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New Dock Projects in New York Bay.

There are few dock problems of more interest to the student of broad engineering subjects than those presented by the improvements of the shipping facilities at the port of New York. Although the extent of the water front and channels is unusually favorable for shipping, the shape of the land is unfavorable. Manhattan Island is essentially a very long and very narrow tongue, reaching down from the mainland at the north, and is practically without direct railroad freight handling facilities. It is true that the New York Central Railroad has a freight line running down the west side of the island, but this is used almost exclusively for handling perishable fruit and food-stuffs. The enormous population concentrated on the island makes its waterfront very valuable for piers for important passenger steamship lines, both coastwise and oceanic. The extent of this passenger business and the high-grade freight handling associated with it has made the Manhattan docks extremely valuable. As a result it is practically out of the question for bulky, low-grade freight to reach the Manhattan water-front directly, because the vessels carrying it cannot afford to pay the dock charges which are very properly required for the wharves along the island. Vessels carrying this low-grade freight have to be accommodated on the water-front of Brooklyn or New Jersey. The freight they carry, together with that brought to the North and East rivers by railroad, is transferred to the Manhattan piers by a system of lighterage and car floats that is extremely economical. At first sight this method of handling freight about the harbor may appear to be crude and expensive, but when it is investigated in detail, and all possible substitutes for it are studied, its merits are very apparent. The details of it are too numerous to be mentioned here, but anyone interested in transportation affairs will find them well worth investigation.

The problem of the harbor at the present time is manifestly one of affording facilities for the receipt and shipment of low-grade freight and of providing sites for factories in the vicinity of the wharves where these materials are handled. Only those engineers who have looked into the subject thoroughly appreciate how closely the interests of manufacturing and those of dock facilities for low-grade freight are associated. While Mr. J. A. Bensel was commissioner of docks and ferries of New York City, he inaugurated one of the most important undertakings of this nature which the city has ever entered upon. The Bush Terminal Co. had demonstrated that warehouses and factories are a profitable investment on the South Brooklyn waterfront, and the city accordingly determined to build a great series of wharves there which will accommodate a large number of vessels. These wharves are so situated that private capital will be able to build warehouses and factories near them and thus, by the co-operation of the Department of Docks and Ferries and private capital, relief will be afforded for a considerable number of shippers and industries. Owing to the system of car floats and lighterage already mentioned, these wharves are practically connected with every railroad system reaching the waterfront, and a warehouse or a factory located back of one of these new municipal docks will be able to ship its materials to any part of the country with little difficulty. These piers are reached so easily from the lower end of Manhattan that their completion will doubtless result in attracting to them some of the companies whose vessels are now docked on Manhattan Island, thus relieving the congestion along the waterfront of the latter.

While this improvement by the City of New York is of great importance, it is rivaled in interest by that which the City of Newark now has under consideration. Newark is one of the largest manufacturing centers in the United States, and is fortunately situated with respect to railroad connections. About one-third of its area is soft meadow land, underlaid at a depth of about a dozen feet by a compact stratum. Newark Bay affords access to this meadow land, which is the largest unoccupied tract suitable not only for wharves and docks, but also for manufacturing purposes, in the vicinity of New York City. Just why the property has remained undeveloped so many years is something of a conundrum, for the improvement of Newark Bay has made the potential value of the land extraordinarily high. At this place trunk railways have already built their lines, a large population is available from which to draw workmen and dock hands, and an arm of New York Harbor will enable vessels of large size to pass freely up to the future wharves. It is not at all surprising, therefore, that the authorities of Newark have at last determined to develop the natural resources of this meadow land, and a commission has been appointed for suggesting the best method of carrying out the work. Its cost will be high, but the people of Newark are convinced that the expenditure will be well warranted not only by the indirect returns of making Newark a seaport, but also by the direct returns which can be obtained from the leases of the wharves, the sale of land and the great increase in taxable values. Newark is as well situated for shipping purposes as New Orleans, provided it will develop the meadow land in the same way that the people of New Orleans developed the mud banks along the river-front of their city. Newark is far better off than Manchester, which has constructed an enormously expensive canal in order to become a seaport. The meadow land at present is a danger to public health on account of its low-lying and marshy condition, being the breeding place of the swarms of mosquitoes that have made New Jersey famous. By dredging a big ship canal, diking and draining other portions of the land, building walls, roads and other works, this tract will become one of the most valuable parts of the city instead of a plague-spot as at present. The project is interesting not only as one portion of the general improvement of the shipping facilities of New York, but also as an example of municipal ownership undertakings of an unquestionably proper character.

Time Limits to Contracts.

While it is true that contractors very often succeed in obtaining their full contract prices for work which they do not complete within the time limits stipulated in their agreements, nevertheless cases arise from time to time which indicate that it is a very desirable thing as a matter of business prudence for contractors to pay particular attention to the maintenance of a proper rate of speed in the execution of their work. The United States Circuit Court of Appeals has just decided a case of this sort. It was an action brought by Owen Brothers against Giles & Glassie to recover money paid to other parties to complete the contracts which the defendants had undertaken to perform. The plaintiffs were sub-contractors under McIntosh Bros. for the construction of a road for the Chicago, Milwaukee & St. Paul Ry. in Iowa. The plaintiffs let two portions of their sub-contract to the defendants. The latter agreed to perform the work in accordance with the McIntosh contract, which required the contractors to begin work within 20 days from the date of the agreement and complete it on or before Aug. 1, 1902. The contract further provided that if the contractor neglected to progress with the work as fast as the chief engineer considered necessary for its completion by the time specified, the railway company might declare the contract abandoned and let the work to other parties, charging the cost to the contractor, and deducting it from the retained percentage or from any payment that was due under former or subsequent estimates. After this contract between Owen Bros. and Giles & Glassie had been signed, another was signed between the same parties, which did not expressly embody the reference to the McIntosh contract, as was the case with the first contract. It was specifically prescribed in the second agreement that the work embraced in it should be completed on Oct. 1, 1902. On that date about half of the work covered by the second contract was still unfinished, although the railway company's engineers, the general contractor and the sub-contractors had previously united in urging the defendants to increase the number of their teams and men so as to complete the work on time. When the date for the completion of the contract was reached, the general contractor put a large force of men on the work, in addition to those of the sub-contractor and finished it up as quickly as possible. The cost of this extra work was met by the general contractor, who charged it against the plaintiffs, who in turn brought this suit to obtain it from the defendants. The court ruled "that the time specified for completion was of the essence of the defendants' contract, and that such time having expired with a substantial part of the work uncompleted whereby the company became entitled to complete it at the plaintiffs' expense, the plaintiffs had the right for their own protection and without the defendants' consent, either by themselves or through the company or the principal contractor with their consent to put a force on the work to assist in its completion, and to charge the defendants with the actual cost of such work to them."

There is one feature of this matter which it is important to observe in view of a decision rendered by the Kentucky Court of Appeals on Oct. 30 of last year in the case of the Louisville & Nashville R. R. against the Mason & Hoge Co. The latter undertook to build 15½ miles of railroad for the former, under a contract which stated that "the said contractors agree to commence the said work within 10 days from the date of this agreement, and to proceed with and complete the same to the satisfaction of the engineer by Feb. 1, 1904, and it is further agreed that the time herein stipulated shall be considered as of the essence of this agreement. And it is further agreed that if the said contractors fail to complete said work in accordance with this contract and the specifications, a part thereof, by Feb. 1, 1904, that then they will surrender to the Louisville & Nashville R. R. Co. all the retained percentage due them under this contract; and they hereby agree with the Louisville & Nashville R. R. Co. that it may hold as its own the whole of said retained percentage as reasonable liquidated damages for the failure on the part of said contractors to complete said work by Feb. 1, 1904, and it is hereby distinctly agreed by the parties that they do hereby fix the liquidated damages for the breach of this contract, as aforesaid, with respect to the time of the completion of the work at the amount of all of the said retained percentage, whatever it may be, on Feb. 1, 1904." The contractors did not begin the work within the time named and they failed to complete it until May, 1905. The railroad did not insist upon its right to terminate the contract when the work was not completed by Feb. 1, 1904, but allowed the contractors to continue their operations as before. The railroad company continued to hold back 10 per cent. of the monthly estimate until May, 1905, and it then claimed the right to hold the 10 per cent. which had been retained because the work was not done within the time specified in the contract. The contractors thereupon filed suit to recover from the railroad company the sum of $18,512.40. Under these circumstances the Kentucky court ruled that all the reserved percentage due to the contractors at the date of the expiration of the contract might be retained by the railroad company as liquidated damages, its right to this money not being waived by not terminating the contract at the expiration of the contract period and by allowing the contractors to complete the work. Although the railroad, on the failure of the contractors to complete the work within the time specified, had this right to retain the reserved percentage, the court ruled that the railroad had no right to retain the stipulated percentage on work done after the time fixed for the performance of the contract. As a corollary of this decision, the court further ruled that where the construction of a railroad was not completed within the time specified in the contract, but the contractors continued to work with the consent of the railroad company, the latter thereby waived its right to rescind the contract and was bound to pay for the work at the contract price and the contractors were bound to complete the work within a reasonable time, failing in which they would be liable for the actual damages thereby sustained. This decision, coupled with that previously mentioned, shows very clearly the desirability of following the old plan, approved by business experience during many centuries, of taking prompt legal action at the expiration of any contract and thereby avoiding throwing upon the courts the burden of determining the equities in a dispute about matters which will rarely come into conflict if the contract is not allowed to run by implication past the time it stipulates for the completion of the work.

Handling Construction Work on Reduced Appropriations.

In the execution of large engineering projects, it sometimes happens that the appropriations necessary to carry through the work on the lines originally laid down have to be reduced by the executive officers of the company or municipality for which the construction is being done. Few more difficult tasks confront the engineer than the direction of a job of this character, for in the majority of cases the conditions are unfavorable to the exercise of a free hand, either in the modification of the original design to meet temporary needs or in actual field construction. If the work is far advanced when the order comes to carry it to a temporary completion, the unit cost of the work may run up to an almost prohibitive figure, though after the work is considerably more than half done it may work out more favorably so far as the cost of the job as in part finished is concerned. If the work has to be cleared of all construction equipment and supplies before the balance can be handled, the cost will inevitably be raised for the work as a whole, unless at the later period the cost of labor or materials takes an unexpected drop.

An engineer charged with the responsibility of producing economical results either in field construction or operation in a case where the total appropriation has been cut, ought to state his position with the utmost frankness before accepting such duties. It is not infrequently the fact that a non-technical board of directors will expect the same economy in a partially finished piece of work as in the installation if carried to the logical conclusions of the original designs. It is most important that the engineer who takes up this kind of a task shall determine to his reasonable satisfaction what sort of construction economy and what sort of operating efficiency he can count upon in a partially finished piece of engineering before he assumes charge of the problem. Otherwise, when the system is put in commercial service with less than its ultimate capacity to handle the business at the best economy planned in the original design, the engineer in charge may find that his superiors are disappointed with the results. For example, a new power plant of 10,000 kw. ultimate capacity may be designed with the reasonable expectation of producing electricity at a cost of 0.6 cents per kw-hour. If the completion of the plant has to be stopped when a capacity of 3000 kw. is reached, perhaps, for perfectly legitimate reasons, it may easily work out in that particular instance that the construction cost of the temporary plant per kilowatt will prove to be $200 or more, against a final cost per kilowatt of $120, and because of the cut in appropriations the cost of completing the plant, when the time finally comes for the work to be pushed to its conclusion, may exceed by several thousand dollars the cost had the original plan been followed of building to full capacity for the size of installation contemplated. The fact that in most power installations the ultimate capacity is not intended to be completed at first does not alter the case for the plant which for lack of an expected market or other financial reason cannot be built as large as was at first planned. And so the 3,000-kw. station may not be able to produce current under the conditions that prevail at its site at a lower figure than 0.8 cents per unit, though in other parts of the same State it may be that a plant of 3,000-kw rating may generate power at 0.7 cents. It is clearly to the advantage of the engineer to know just where these differences in cost come in, for it is a natural course for his superiors to compare the production costs of both plants of the same general size without making allowances for the differences in conditions that enable one to make a better showing than another.

The real problem before the engineer who takes charge of work is how to push it through at the lowest cost and in the shortest time consistent with good results. In many cases he may not be held to account for the operating economy of the partially finished plant, but whether he is or not, it is plainly his duty to handle the job to the best of his ability, and to leave as small a difference as possible between the anticipated and the actual cost, both of construction and operation. In some cases this kind of a task cannot be done without tearing out a part of the first work; in others, the original design can be followed to a certain point, when temporary construction of a special nature must be carried out, to be later replaced by the permanent construction of the original design. The possible complications are too numerous to be reviewed at this time, but the foregoing points must be looked after in the handling of the work.

Notes and Comments.

The Gasoline or Kerosene Engine seems to have been neglected in a surprising manner by contractors. Although its field of usefulness, in connection with contracting operations, is much more extensive than that of the electric motor, the latter has forged into public favor much more rapidly. Possibly one reason for this is that the salesmen employed by the central-station companies have succeeded in convincing builders in the large cities where current is available that motors are a source of ultimate economy, although the cost of current for them may be quite high. There has been nobody to urge the advantages of the internal combustion engine, however, upon contractors, and as a result, comparatively few of them have been employed, even when the cost of providing fuel for a steam boiler is so very high that the adoption of a kerosene or gasoline engine is a self-evident source of economy. Possibly one reason for this reluctance to use such engines is the recollection of the unreliability of some of the earlier types which were put on the market. There still are some engines which demand all kinds of care in order to make them run, but all through the Western States, and to some extent in the East, the farmers have been employing gasoline and kerosene engines of a rugged character with much success. They have even won their way into popular favor in the most unfavorable class of service possible, that of driving fishing boats on the seacoast, where the constant presence of dampness and dirt tries the reliability of the ignition system very severely.

The Pueblo Water Supply, described on page 399 of this issue, is one of exceptional character in several respects. In the East, where plenty of water is available, although the quality may leave something to be desired in some cases, the actual scarcity of water that exists in the dry country about Pueblo does not complicate the problems the engineer must solve. The legal questions regarding rights to surface water, the turbidity and pollution of the water of the river flowing through the city, and the alkalinity of the local well water made it necessary to develop the underflow in a gravel stratum about 12 miles from the city. Although the water-bearing gravel overlies the bedrock in the valley of the Fountain River, the waters of the stream are kept out of the stratum by the cover of fairly impervious earth and the supply comes from the melting snows in the mountains, where the gravel outcrops. As a result of this condition there is an abundance of subsurface water at all times, although the river bed is frequently dry. The supply is not only one of the largest ground-water developments in the country, but is probably unique in being delivered to the consumers under a pressure of 100 lb. at the hydrants in the business district, solely by gravity. The water flows from the collecting well of the infiltration pipes to distributing reservoirs 2 miles from the city, and thence into the street mains, without being pumped up at any point. While the system as a whole is unusual, the extensive use of concrete and riveted steel pipe for the aqueduct will at once attract the attention of the designing engineer, and will emphasize the important influence of freight rates on the total expense of cast-iron pipe lines in that part of the country. Another feature of the work which deserves special consideration is the use of trench excavators and trenching machines, which proved particularly useful for reasons that are fully explained in the article.

High Buildings were rendered financially possible by the development of the elevator, and on this account The Engineering Record has kept its readers informed concerning all improvements in such machinery. The design of a steel-cage frame for such structures was a naturad adaptation of the principles of bridge design to an architectural condition that arose when the thickness of masonry walls was increased by added height to such a degree that the floor space in the lower stories was seriously curtailed. These things are well known and have been often described. The development of the modern types of foundations for such lofty structures has not been described, however, except by independent articles on the work done for individual buildings. A considerable number of readers will, therefore, find the review of the development of building foundations, on page 412 of this issue, a story of unusual interest. It is probably the first explanation of the evolution of foundation works of all types for high buildings and deserves thoughtful consideration on account of one feature of foundations that has often been overlooked in the past. As the business districts of cities develop, the construction of deep-level sewers and sometimes of subways, not to mention the great pits in which the subsurface parts of high buildings are buried, tends to change materially the normal ground-water level. The preservation of timber piles depends on keeping them below this level, and consequently on foreseeing what fluctuations may occur in it. The deterioration of timber piles under lofty buildings, owing to the sinking of the ground-water level, has been observed enough times to lead some architectural engineers to avoid their use except under conditions of manifestly insured safety for all time. Some criticism is generally made when caisson foundations or concrete piles are used, on account of the greater expense to secure results which timber piles would yield; this additional expense pays for absolute permanence under any condition of the ground-water level and for greater security in case deep excavations are made for adjoining buildings. The problems that arise in executing such works are often of great difficulty, as the article points out, and must be solved by the exercise of good judgment based on experience.

The Extraordinary Cofferdam or Caisson used by the contractors for the second dry dock at the Mare Island Navy Yard, described on page 428, is probably the leading novelty illustrated in this issue. Like some other large dry docks, this one was too difficult for the original contractor, who made two unsuccessful attempts to lay the site bare by using coffer dams of the ordinary type, having a core of earth between lines of sheet piling. The second contractor decided to try an entirely different type of structure, consisting of a single row of vertical sheet-piling held in place by five courses of horizontal longitudinal and transverse struts, the whole forming a caisson extending 9 ft. outside the limits of masonry on every side and sustaining a hydrostatic head of nearly 50 ft. About 4,000,000 ft. of timber have been employed in this caisson and its cost has been heavy; on the other hand, the difficulties of the first contractor have been avoided and the stability of buildings in the vicinity has not been endangered. The caisson is supported in an ingenious manner on the piles driven for the foundation of the dock. The site was first dredged to a uniform depth of 40 ft. below low-water and then 12,260 piles were driven and cut off 36 ft. below low-water. The framing of struts was then built up over the site and sunk by piling pig iron on it until it rested on the piles. This work was not so easy as might be expected because the piles had become covered with silt or peat to a depth of several feet in some places, which had to be removed by a hydraulic jet and an orange-peel bucket operated through the pockets of the timber frame or crib. When the latter was finally in place, the 12 x 12-in. sheet piling was driven around all four sides, its total length being 1,960 ft.; the cost was somewhat reduced by driving the piles in pairs, which resulted in a saving of a considerable sum as explained in the article. When the work was completed it was carefully inspected by divers and patches put on wherever any defects were found. The pumps were then started, and as the water level was lowered, any leaks that were found were plugged. Trouble was experienced in making a few places water-tight in the bottom, along the sheeting, but after these had been covered with concrete or puddle, it took two 15-in. centrifugal pumps only three days to unwater the site. The location and puddling of the leaking parts of the bottom was a tedious operation lasting 21 months, but the excellent working facilities afforded by the completed cofferdam are considered to more than compensate for the expense and time involved, and the construction is proceeding so rapidly now that it is expected the contract will be completed by the end of the year. It is not often that a dry-dock is constructed on a submerged site, and for this reason as well as on account of the novel methods employed, the work is of unique interest, ranking in this respect with the righting of the overturned caisson of Baltimore Light, described in detail in this journal on March 14.

Subway Construction in New York has taken on a decidedly encouraging aspect since the Board of Estimate voted on March 27 to proceed with the construction of the whole of the so-called Fourth Ave. route from the Brooklyn end of the Manhattan bridge to 40th St., running parallel with and a block from the Fifth Ave. elevated railway. This portion of the Borough of Brooklyn has a population that has been demanding better transportation facilities more vociferously than the people of any other section of Greater New York, although there is considerable doubt whether this subway will prove useful to so many people as one along the Broadway-Lexington Ave. route in Manhattan. The significant fact is that the board actually voted to proceed with the construction, indicating an appreciation of rapid transit needs that is gratifying. It was announced in some of the newspapers that this was the final step necessary to leave the way clear for making the dirt fly, but such a statement was quickly disproved. The Public Service Commission sent the forms of contract for the undertaking to the Corporation Counsel for approval, but this approval was refused on the ground "of the apparent lack of appropriation to complete the work covered by the contracts." The Comptroller has also announced that he will not certify the contracts until he is certain that the city will be able to pay for the work covered by them. The Public Service Commission has decided to pay no attention to these obstacles, however, but to call at once for bids on the work, which will be divided into six sections. So the situation again simmers down to an uncertainty concerning the degree to which the city has approached its legal limit of indebtedness. Apparently nobody knows just how to answer that question, or, if he knows, is willing to say anything about it. Consequently the citizens of New York are confronted with the edifying spectacle of all their chosen representatives being unable, even with the credit of a great city behind them, to accomplish as much as Mr. Fisk and Mr. Oakman and Mr. McAdoo have been doing with their Hudson & Manhattan Ry. extension in Manhattan. It is not wholly improbable, in fact, that the recent vote in the Board of Estimate for the Fourth Ave. route was so favorable because some of those voting for immediate construction recognized that the financial condition of the city would probably prevent any early signing of contracts. The people urging the speedy building of the subway would be pacified for a time by such a vote and there would still be an opportunity to amend the Elsberg law so that private capital would be warranted in undertaking the work. The fact that the Legislature is now discussing such amendments indicates that this view of the recent action by the Board of Estimate may be right to some extent. It is significant that such influential journals as the "Tribune" and the "Eagle," one republican and the other democratic, unite in advocating the construction of these new rapid transit routes by private capital rather than city funds. But in view of the pressing needs of Greater New York for more and safer schools and public hospitals, better equipment for the fire department, better pavements and sewers, and other things of importance now said to be impossible of attainment on account of inadequate funds, it is not surprising that this opinion is held by a considerable proportion of the people. There is little use in paying taxes and keeping children in poor schools for the sake of building works which private capital is willing to construct if it is treated with ordinary business fairness.

THE CONSTRUCTION OF THE THIRTY-NINTH STREET BUILDING, NEW YORK.

By E. P. Goodrich, Consulting Engineer, New York.

It is not often that a single generation witnesses the evolution of a mechanic art or a complete revolution in method or product of one of the industrial processes of civilization. The sudden growth and wonderful possibilities of wireless telegraphy and of rapid transit, culminating in aerial navigation with mechanisms heavier than air are constant topics of interest for the popular press. While the arts of communication and transportation have thus achieved wonderful advances within the memory of many, the art of shelter has also evolved, although perhaps not so spectacularly. When one reads such quotations as the following from a body of artists it behooves the commercial and professional man also to awake and see what is meant by the evolution therein hinted at: "But to-day. . . . it would seem as though architecture were on the verge of an awakening. Commercial architecture with us is beginning to feel the thrill. Abroad monumental architecture, as well, is showing signs of a renewed joy in life, and structural concrete, both of itself and embellished with richer materials, furnishes the new and seemingly adequate medium of architectural expression."

From the reinforced concrete flower pot of the French gardener to the modern concrete office building or country residence is a long path, and few persons realize the rapidity and interesting course of the evolution which has taken place. A single generation has witnessed this development, and perhaps it is emblematic of the genius of America, with its liberalism and scientific spirit, that what is probably the best example of the highest evolution of this art exists in the heart of the metropolis of this continent and houses a great publishing house devoted to the dissemination of engineering knowledge in almost every branch.

On the north side of 39th St., in the Borough of Manhattan, New York City, between Seventh and Eighth Aves., distant but a short walk from the new Pennsylvania Railroad passenger terminal, the Grand Central Station, the Times Square subway station and numerous existing and constructing transportation lines, is the Thirty-ninth Street Building, the home of the McGraw Publishing Co. Besides being somewhat unique in its environment and occupancy, it is especially so from a structural point of view.

Beside the transportation lines above mentioned which tap the neighborhood of this building, there exist electric surface lines on Broadway, Seventh and Eighth Aves. and 42d St., each within three blocks, while the Sixth and Ninth Ave. elevated stations are but slightly further away. With the completion of the Belmont tunnel under the East River, which will be extended to Times Square at 42d St. and Seventh Ave., and of the Hudson Companies' tunnels under the Hudson River, which will be extended to 33d St. and Sixth Ave., the site will be rendered still more accessible. The hotel and theater districts are in the immediate neighborhood, and the building is but slightly removed from what would be the center of gravity of the engineering district, comprising the Engineers' Club, the Engineering Societies Building and that of the American Society of Civil Engineers.

The building occupies a lot 126.3 ft. wide and 99.6 ft. deep and was designed to be mainly occupied as a printing establishment. That fact determined the arrangement of columns and the floor heights. It also dictated as fireproof a structure as possible, on account of the inflammability of the paper, ink and other materials. The building had, at the same time, to be so designed as to be available for office purposes. The rapid strides being made in the use of reinforced concrete, together with its fire-resisting qualities, suggested to the enterprising owners that they might give a considerable impetus to the progress of this art by erecting a structure which would mark the very latest development in reinforced concrete building work, and at the same time secure for themselves a most serviceable and satisfactory home. In this building was to be accommodated the organization handling the editing, printing, binding and distributing of the periodicals owned by the McGraw Publishing Co. and other similar concerns. Those of the former company now include the *Electrical World*, the *Street Railway Journal*, the *Electrochemical and Metallurgical Industry*, the *American Telephone Journal* and *The Engineering Record*. It is plain that an organization to be effective and handle those publications, with their annual issue of over two and a half million copies, must take advantage of concentration, consolidation and unification in every particular, and that only a building of the highest type could supply all the elements necessary to the successful accommodation of such an executive and mechanical plant as could meet the needs of the case.

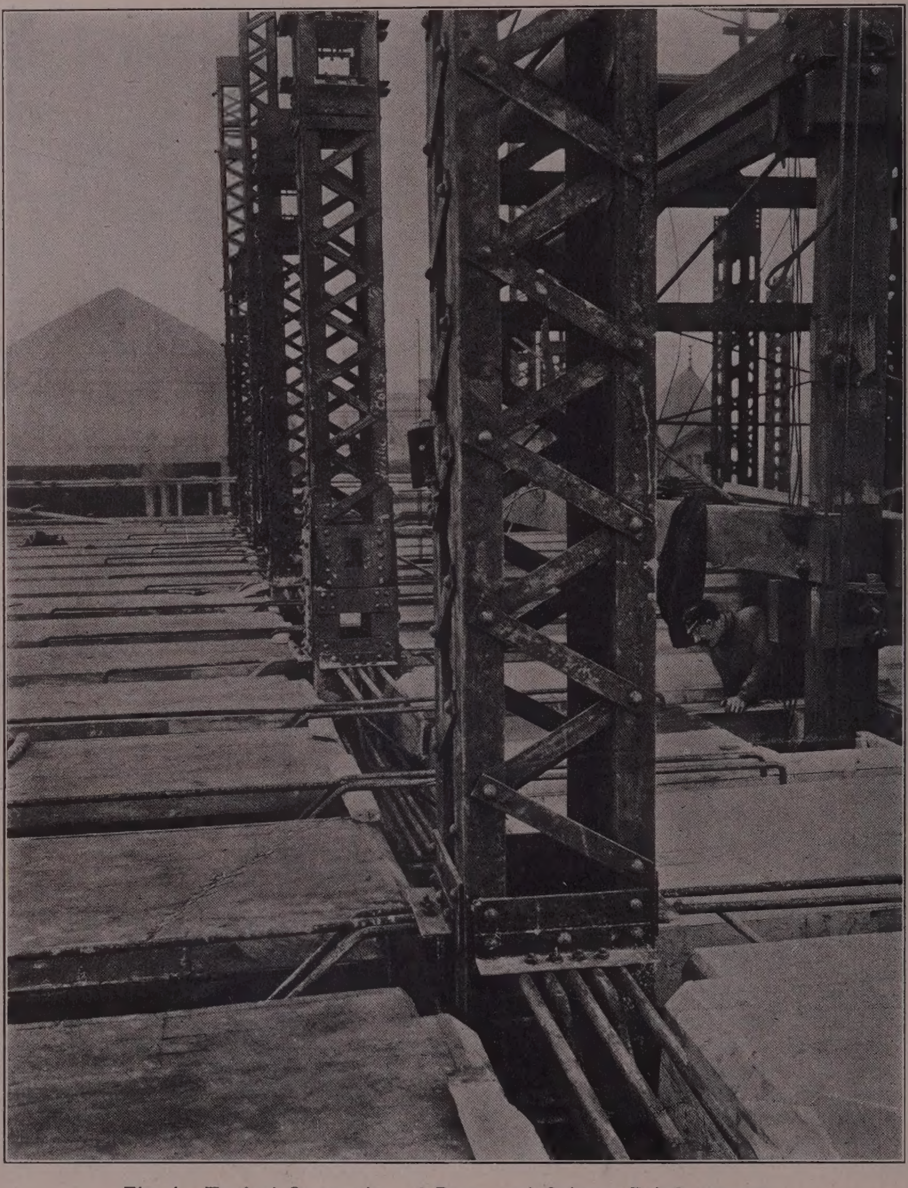


Fig. 1. Typical Connection of Beam and Column Reinforcement.

While not definitely known at the time the building was designed, it was surmised that heavy loads would have to be carried on the lower floors and that printing presses might be located on any of the other floors. It so happens that the first floor has been leased for a Post Office sub-station and is often piled high with heavy mail matter. The Federal Printing Co., which is the printing department of the McGraw organization, occupies the second, third and fourth floors and operates 18 stones where forms are made up, 6 linotype machines, 2 monotype composing machines, a type-casting machine, 14 electrically driven Miehle printing presses, 8 small platen presses, 6 folding machines, a gathering machine, a covering machine and a continuous trimmer. Some idea of the amount of work done in this establishment and the floor loads sometimes carried may be obtained when it is known that the presses are capable of 140,000 impressions per day, while the bindery will turn out about 100,000 eight-form magazines per week. At the present time over 2,000 bags of mail are being sent out each fortnight.

Besides being designed to accommodate such conditions as those above described, the design of the building was undertaken at a time when the newspapers were full of details of collapses of reinforced concrete structures and just at the time of the terrific tragedy in San Francisco. The consequences were that a building was designed and erected which is as nearly proof against the forces of nature—even those of conflagration and earthquake—as it is within human possibility to devise. The few reinforced concrete builidngs inside the zone of tremor in San Francisco almost completely demonstrated the facts already brought out by Japanese engineers with their reinforced concrete models erected on great shaking tables, that reinforced concrete is an exceptionally good vibration and shock resisting material. While New York City is not located in a seismic region, still it was thought wise to design with regard to a possible disturbance of that kind, and certain details of construction were devised, in part, at least, to provide against danger from that source.

All columns, beams, girders and floor slabs were treated as continuous, restrained members, and the reinforcement arranged with this point in view. Exactly the same quantity of steel was provided over supports and at the bottoms of beams at their centers, this amount being determined by the formula $1/10\, w\, l$, in accordance with the New York (Manhattan Borough) Building Code. It may be remarked in this connection that that special stipulation, as well as the similar one in all other codes, is somewhat anomalous and really faulty. In monolithic concrete buildings all members are afforded perfect restraint at all points of connection so long as the forms are in place, and cracking of a dangerous nature is more than possible unless all reinforcement is so disposed as to properly assist in securing a continuance of this condition. In the McGraw Building this arrangement is actually provided to the extent described above, so that it is really stronger than recognized by the Building Code in the ratio of 12 to 10, when only the reinforcement over the supports is considered; and is actually stronger in a much larger ratio when the bottom reinforcement is considered (24 to 10 over a part of the beam length).

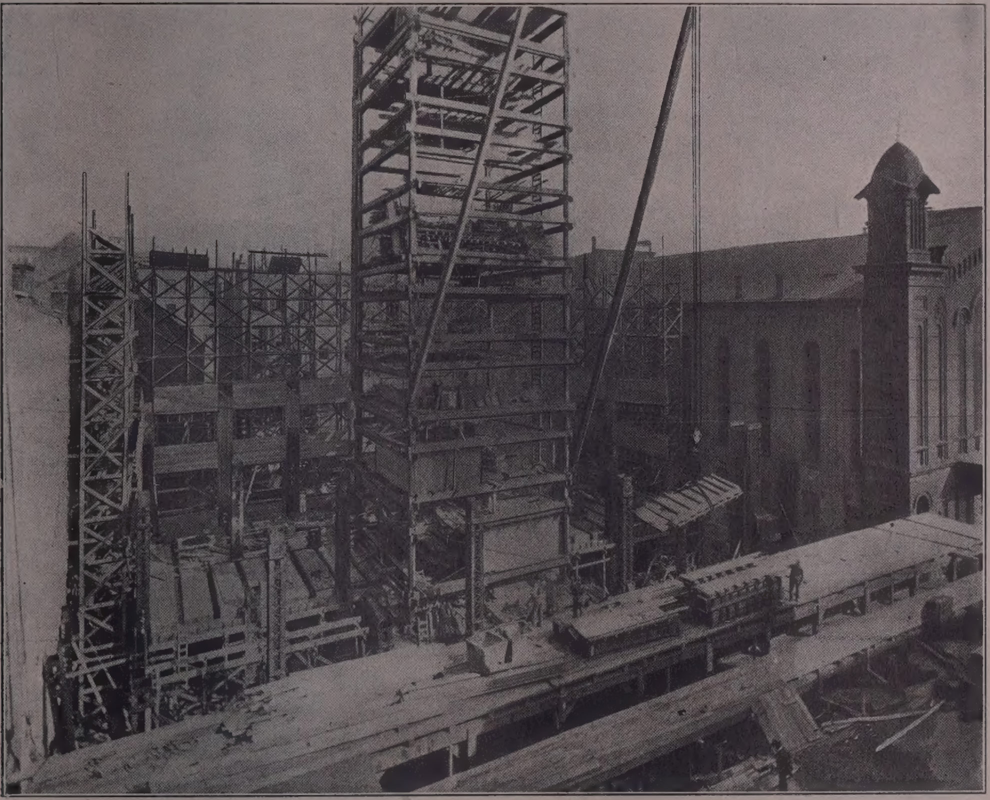


Fig. 2. Central Tower and First-Floor Forms Being Installed.

It is still stronger when it is noted that usual assumptions consider all members as free to turn at all points of support, in the same manner as if supplied with hinges at those places, and when account is taken of the reduction which is made in the tensile stress of the top reinforcement over supports by the presence of steel within the zone of compression. When accurately calculated, except that deflections of supports are ignored, these points affect the strength of the structure so as to increase it easily by 50 per cent, so that instead of the allowable loads of 250 lb. per square foot on the first floor, 200 lb. per square foot on the second floor, 150 lb. per square foot on the third floor, and 125 lb. per square foot for all other floors, including the roof, the floor construction is actually good for 375, 300, 225 and 188 lb. per square foot, respectively, as far as the tensile reinforcement is concerned. All girders were constructed with haunches or brackets at the columns, and on the lower floors the beams which joined columns were similarly built. This was done to reduce the unit shearing stresses at those points and to diminish in a similar manner the compression stresses on the lower sides of the members, due to the negative bending moments near points of support. In almost all cases the floor slab was considered as affording sufficient top compression area for the members, except in one or two cases, where compression reinforcement was introduced. In one such instance the total weight of the rods contained in the girder was nearly two tons. This was made necessary because of the shallowness of the member. The main floor beams had spans of about 21 ft. 9 in. between centers of girders, while the main girders, each of which supported two beams, had spans of about 14 ft. 8 in. less the thickness of columns.

Wall beams were carried above the floor slabs up to the window sills, thus allowing window openings to reach entirely to the ceilings, and thereby affording a maximum of light. All sharp edges of interior floor beams and girders were beveled so as to prevent chipping during construction and in case of fire, and to prevent trouble from shrinkage. Special care was taken to maintain the reinforcing rods a proper distance away from the forms so as to provide them with ample concrete fireproofing. In some members special separators or spacers, consisting of flat iron, specially shaped for the purpose, were employed, but in the majority of cases concrete blocks of proper thickness were molded and placed in the forms, on which to rest the reinforcing rods. These concrete blocks were prepared on special boards fixed for the purpose, having slots at proper intervals, into which fitted sheet metal partitions to separate the blocks. Each block was reinforced with a wire run through its center.

The reinforcing rods for beams and girders varied in size from ¾ in. to 1⅜ in. They were of the usual smooth, round variety, the only method employed of increasing adhesion or anchorage being the hooking of all ends with right-angled bends about 3 or 4 in. in length. In general, floor slabs were reinforced with ½-in. rods in as long random lengths as possible, splices being made by means of long interlocking hooks on adjacent rods, each hook being bent a full 180-deg. turn. The spacing of rods, of course, varied with the loading. Over supports alternate rods were supplied with a yoke-shaped short piece, held at a proper distance above the bottom rods by a block of concrete similar to those placed in the bottoms of beams. The ends of these rods were bent downward at the theoretical points of inflection of the slabs and were hooked under the bottom rods. The concrete blocks extended over the space between three rods and were so spaced and staggered that when the yoke-shaped top rods were sprung into place the whole system was held together with considerable rigidity so that it required much rough treatment to displace any rods. The latter were also supported from the forms by long concrete blocks. This whole scheme was found cheaper than wiring the rods to preserve proper spacing, especially when alternate rods are bent up over supports, as is often done.

In designing the reinforcement the requirements of the New York Building Code were followed as to the use of the straight line rate of variation of compressive stress, the ignoring of the tensile strength of the concrete and similar rules.

The floor slabs were 4 in. thick on the lower floors and 3½ in. thick on those carrying the lightest live load. They had clear spans of 4 ft. 4 in. The concrete mixture employed here, as also elsewhere throughout the building, except in foundations and retaining walls, was 1:2:4, using Dragon cement, Cow Bay sand and ¾-in. crushed trap or washed gravel. Stone of 1½-in. ring was used for the special work mentioned. The outside walls were of concrete, without reinforcement, except in the columns and at floor levels, where, at the latter points, as much steel was introduced as would be necessary in a girder of relatively small depth, even though the walls were actually installed in full story heights at a single operation, thus precluding any true beam action at any point. The 4-in. concrete walls around the smoke flue under the basement floor and around the chimney were reinforced in two directions, as is usual. A 2-in. air space was provided on sides and top of smoke flue under the floor, and a similar insulating air space was obtained in the case of the chimney, through the difference in form of the square shaft section and the elliptical one of the flue itself. The latter was erected by the Alphons Custodis Chimney Construction Co. Cement was purchased under the standard specifications of the American Society for Testing Materials and was all tested at the mill before shipment.

The column foundations rested on the ledge of gneiss which runs so close to the surface in the upper part of Manhattan and outcrops extensively a few blocks north of 39th St. In general, good material was found immediately beneath the building. At a few points only was it necessary to excavate to anything more than an extra foot or two to remove rotten rock so as to secure a satisfactory foundation.

In connection with the design of the columns a modification of the Building Code, as it existed at that time, was requested and granted. Until that time the permissible unit stress on concrete in direct compression was only 350 lb. per square inch. Where longitudinal rods were introduced they might be stressed to twelve times this amount, so that the use of reinforced concrete columns of this type was practically prohibited. Columns of the Considère variety could be employed, and a fair unit stress was allowed under the special regulations which had been promulgated. Prof. Wm.

H. Burr, who had charge of the structural design of the building, proposed to the Building Department that a self-supporting steel frame be employed for the reinforcement of the columns, and that it be of such size and design as to be capable of supporting the whole dead load of the structure at a proper stress. With this variety and amount of column reinforcement, which was to consist of angles battened or latticed together in a skeleton box form, it was considered that the concrete was so closely confined that its stress might safely be allowed to run higher than could otherwise be done. A value of 750 lb. per square inch was finally selected, and the design of the building was prepared on that basis. The largest basement columns were made approximately 33 in. square. Their principal reinforcement consisted of 6 x 8 x 1-in. Phoenix angles, 29 in. back to back, with proper battens and lacing bars. These large angles were necessary because of the necessity of keeping the size of column within reasonable limits and because a ratio of moduli of elasticity of 12 (that allowed by the Building Department) restricted the combined live and dead load stress in the steel to 9,000 lb. per square inch, while that in the concrete, exclusive of the outer 2 in. of fireproofing, was 750 lb. per square inch. A further condition was imposed in the design of the column reinforcement, that at each floor level the steel work in the columns must be sufficient, while acting alone and at a stress of 16,000 lb. per square inch, to support the total dead load above that point. The corners of columns were rounded at a 2-in. radius, and on the upper floors column caps were introduced in the concrete work so as to obviate the necessity of lengthening the floor forms where the diameters of the columns had diminished in size. The structural work forming this reinforcement was often erected three stories ahead of the floor work, but its erection was done by methods which might be improved on a second building.

Some wall columns had eight angles latticed together in the form of a multiple box, at points where great thickness was not obtainable. Of course, all columns were reduced in size with increase of height and reduction of load. The angles of those in the interior became only 14 in. back to back at the top floor. The percentage of steel in the column sections at the several floors varied from 10 per cent. in the basement to 3½ per cent. at the top floor. In the first instance the steel carries 57 per cent. of the total load and in the latter case only 30 per cent. The column sections were in two-story lengths, alternate ones breaking joints. Of course, in the basement and top floors half the sections would be in but single-story lengths. The location of a sub-basement boiler room in one corner of the building produced one very long, heavy section. This one weighed 14.7 tons, and the total length of this column to the roof was approximately 170 ft. The cornice was practically 150 ft. above the curb at the center of the front, or over 160 ft. above the basement floor level. Bridge steel in accordance with Cooper's Bridge Specifications was employed for all columns.

An especially rigid connection between the column steel and the beam and girder reinforcing rods was desired. This was secured by providing on the columns shelf angles riveted to filler plates. The upper edges of the latter were gouged to proper depths and at proper spacings so as to fit the size and spacing of the reinforcing rods. These filler plates were placed with the bottoms of these semi-circular gouges just flush with the tops of the shelf angles, the horizontal flanges of which were punched to receive ½-in. bolts between each two reinforcing rods. These bolts passed through, and held down tight upon the rods, small flat iron strips, thus binding the rods firmly to the shelf angles and preventing lateral displacement because of the gouges in the filler plates. Fig. 1 shows a typical column structure, together with the rods for beams and girders, and illustrates the rigidity of the connection obtained. The latter was so strong that the column erectors often fastened one end of the turnbuckle used in plumbing the column sections directly to the girder reinforcing rods, since they were just as rigid as any other part of the structure. This cannot be said of any other known design of reinforced concrete building. In the case of the top reinforcement of beams and girders the positions of angles, gouged plates, bolts and straps were inverted, but they were equally effective.

Fig. 1 also shows the arrangement of the forms for beams, girders and slabs. The column forms were first erected. Next, shallow troughs were put in place for the girder bottoms and so much of the girder sides as were below the beams. Finally, boxes were set in position, which formed the slab bottoms, beam sides and girder sides combined. These boxes were provided with ledges on which to rest the 2-in. plank forming the beam bottoms, which were the last parts of the forms installed, except the triangular strips which made the bevels on the edges of the beams. The sides and ends of these boxes were made collapsible.

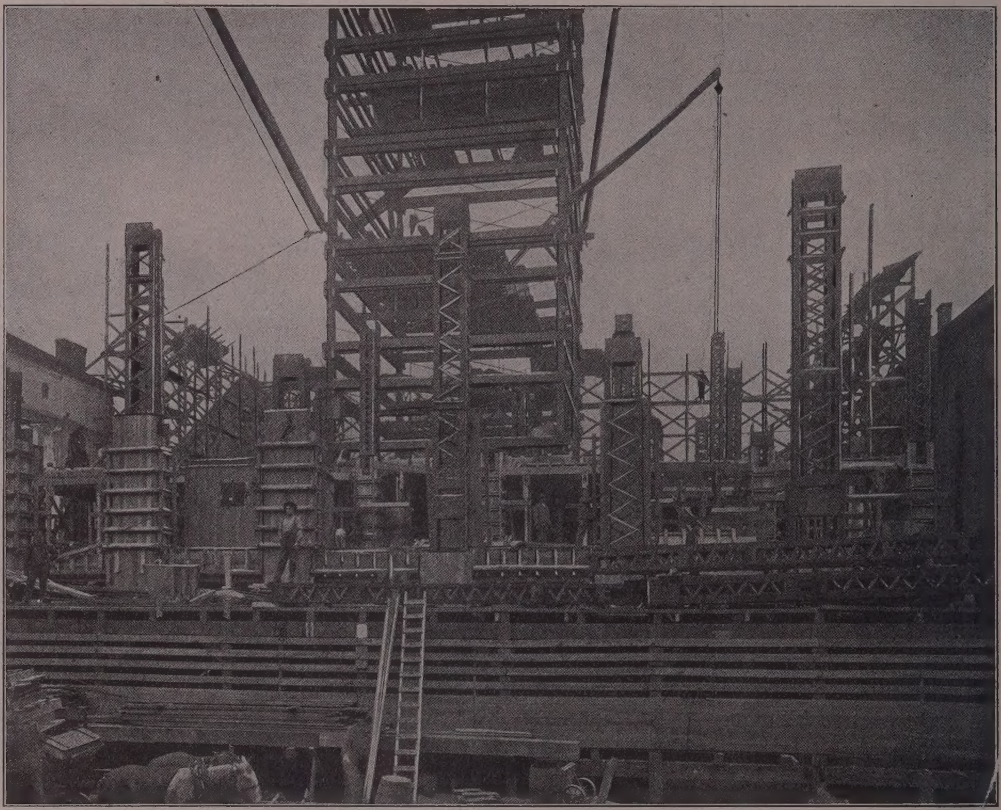


Fig. 3. Steel and Forms for Columns and Bridge over Sidewalk.

The underlying motive throughout the whole work was to handle all materials in large units and masses, and to this end was provided the central tower, with the four derricks on the corners. This tower is shown in Figs. 2, 3 and 4. The forms were built in a vacant lot at some distance from the building site. The congested district and restricted space at the site made this necessary. Fig. 2 shows the condition of the building about the end of October, 1906. In it are seen the lowest sections of the structural columns in their alternate one and two-story lengths, and the floor forms being installed for the two rear sections of the first floor. The right-hand front derrick is shown in the act of lifting several large column side forms, each of which would take six men to handle. On the top of the bridge over the sidewalk are seen girder boxes and column side forms and the ¾-yd. concrete buckets employed in the placing of all concrete for floors, columns and walls.

Two electrically-driven drum concrete mixers were located in the basement so that they would discharge their contents into the elevator pits. The elevator shafts were sheathed from bottom to top, and each derrick could drop a bucket down to the mixer, wait while a batch was dumped, hoist the bucket with wide-open throttle, and when the bucket reached the proper height it could be swung and dumped within a few inches of the desired point. This method obviated the use of special concrete hoists, special hoppers, wheelbarrows or carts trundled over the forms on special runways, but its ultimate economy is open to question.

The derricks were operated with Lidgerwood double-drum hoisting engines located in the basement. Signals were transmitted electrically to the engine men by signal men stationed high up on the central tower. The booms were long enough to reach all parts of the building within an arc of about 250 deg., with its center at any corner of the tower. Special corner castings held the lower ends of the booms, and heavy forgings were employed on the tower for the sheaves through which the head lines ran. The two front booms could reach to the center of the street, and often a whole truck load of lumber, of forms or of reinforcing rods was lifted in one operation and placed practically at the required point.

The tower had 10 x 10-in. yellow pine corner posts, 31 ft. apart, 4 x 12-in. horizontals and 1½-in. diagonal tie rods. The horizontals were located so as to come close above and below each floor, and the diagonals were installed between floors only. Holes were left in the floor concrete for the corner posts, which were filled after the tower had been removed upon the completion of the building. The booms were 75 ft. long, of 12 x 12-in. yellow pine, and were first installed about 50 ft. above the street. They were raised from time to time as the work progressed.

Fig. 3 shows the building about Dec. 1. In it may be seen the heavy column forms and bracing. These columns were each concreted with about three buckets of material, run in rather wet and carefully puddled during the whole operation. The filling of a single column would thus take less than 10 min., and very heavy pressures were encountered, as witnessed by the breaking of one of the lower 4 x 4-in. pine crosspieces on one of the columns shown. Column sections were not reduced at each floor, but usually at alternate floors, except for the caps, as described above. In general, the forms were left in place 30 days, four complete floor sets having been provided, and an average rate of a story in 12 calendar days was maintained throughout the months from November to April, in spite of extreme weather conditions.

Fig. 4 shows the building about the middle of January. A scaffolding was erected across the front of the building to provide a working platform for the workmen who installed the cast concrete ornamental work, the bronze faciæ and the stucco finish. It was also of assistance in the erection of the concrete form work. At the left, just above the top of the house, may be seen one of the large wall panel forms, and just slightly higher is visible a small piece of the canvas used to enclose the space over which concrete was being deposited for the floor.

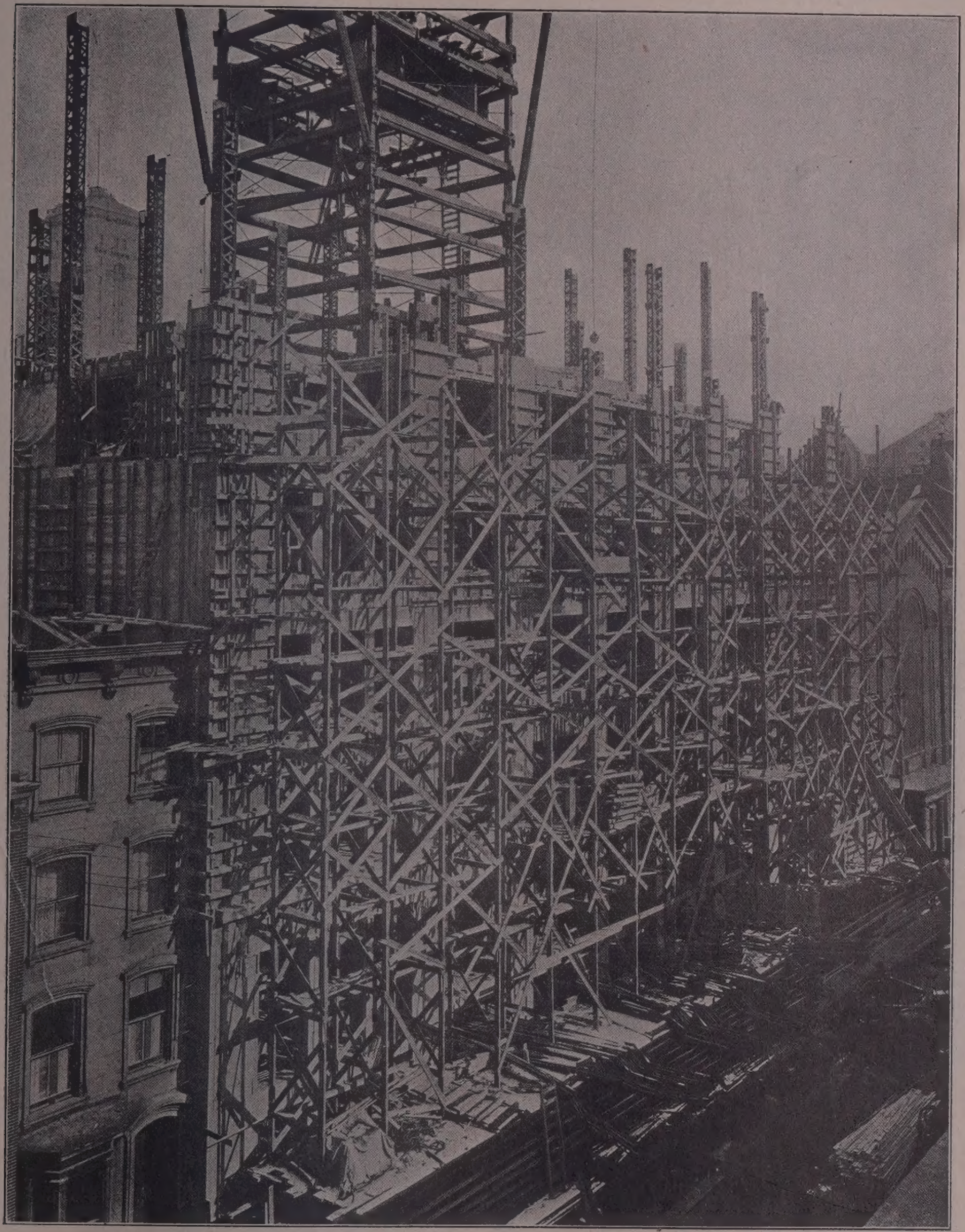


Fig. 4. Front of Building when Seven Stories High.

The cast concrete ornament was set in slots and depressions molded in the mass concrete, and galvanized iron ties were employed for fastening. Moldings were run in place. Special ¼-in. anchoring and reinforcing bracket rods were cast in the mass concrete to support heavy molded work, and dove-tailed slots were formed in all surfaces were special anchors could not be placed. These dove-tailed slots were secured by using three dove-tailed strips side by side, the center one being placed in a position reverse to the outer two, so that it could immediately be withdrawn when the forms were removed and then the other two slipped sidewise and taken out. The scheme proved eminently satisfactory. The stucco was of Portland cement and crushed marble and was applied in three coats to a thickness of 1 in. The interior of the building has been plastered directly on the concrete, except that a patent bonding compound was first applied to the concrete surface. The main entrance is finished in imitation Caen stone.

During the winter months artificial heat was provided to prevent the fresh concrete from freezing, and the latter was also mixed with hot water and the materials heated. Water barrels, provided with a steam jet and an automatic water shut-off valve, were installed on the first floor over the mixers. The water was kept practically boiling all the time, and the mixing operation was so rapidly carried on that the concrete would usually reach the point of deposit at a temperature of about 70 deg. Fahr. Numerous salamanders, burning charcoal, were provided and maintained night and day under the newest work, and, even in zero weather, the temperature within the enclosure made by the canvas stretched around the work never fell below 50 deg. and was often actually found to be 100 deg. up inside the floor boxes where the air could not circulate. The fresh concrete was always protected on top by a canvas cover held about 6 in. above the floor surface by special strips, and the hot air from below was allowed to come up and circulate in this space through the holes left in the floor for the electric outlet boxes and steam pipes. Salt hay was also spread on the top canvas, and the various precautions taken to secure quick set and prevent freezing were so effective that no indications of cold were ever discovered, except occasionally as a slight checking of the slab surface.

Maple floors on pine nailing strips bedded in cinder concrete form the wearing surfaces, except in stairs, halls and toilet rooms, where special stair treads and terazzo floors are provided. The windows at sides and rear have wire glass supported in hollow metal frames. Those in the front, with less exposure, are of the usual type.

Even without a sprinkler equipment, an extremely low insurance rate is allowed, because of the almost perfect protection provided. Doors into halls and stair and elevator shafts are standard metal covered, with wire glass in all openings. At all points the greatest care has been exercised to make this building the very best possible in this respect.

Four electric elevators, three for passengers and one for freight, serve the building. They were manufactured by the Marine Engine & Machine Co. The elevator machinery is installed in pent houses over the elevator shafts. The two passenger cars at the main entrance have capacities of 2,400 lb. each and are 5 x 6½ ft. in size. The other passenger car at the other end of the building has a capacity of 3,000 lb. and is 7 x 5 ft., being designed for both freight and passenger service. The freight elevator proper is of 4,500-lb. capacity, with a car 7 x 6½ ft. in dimensions. There is also an elevator to serve the third, fourth and fifth floors, especially for the use of the printing department, and a sidewalk lift for freight destined for the basement.

Electricity for the operation of the elevators and the other machinery in the building and for lighting is supplied for the New York Edison Co. on a 240-volt two-wire power circuit and a separate 120-volt, three-wire lighting circuit. The former has a capacity of 360 hp., and each outside leg of the latter will carry 360 amp. The switchboard has eight 200-amp., six 100-amp. and two 150-amp. double-pole single-throw fused knife-switches on the service panel, and sixteen 50-amp. three-pole single-throw fused knife-switches on the lighting panel. There are twenty-seven power feeders and an equal number of light feeders for distributing the current throughout the building.

Although current is now purchased from the Edison company, space is provided for the installation of engines and generators, should occasion arise, and two 200-hp. Babcock & Wilcox water-tube boilers are in place, but are now used only for heating purposes. The mechanical equipment was designed by Mr. W. S. Timmis, consulting mechanical engineer.

It was the endeavor of the architects, Messrs. Radcliffe & Kelley, to produce a building which would be pleasing in appearance and yet disclose even to the casual observer that it was monolithic in character and concrete in material. That all those connected with the design and construction succeeded admirably in the endeavor made can only be adequately appreciated by a visit to the building itself.

Two Gasoline-Propelled Fire Engines have been ordered for the Fire Brigade of London, England. They will have a maximum speed of 30 miles per hour on the level, and carry pumps with a capacity of 500 gal. per minute.

SOME RECENT IMPROVEMENTS ON THE UNION PACIFIC RAILROAD.

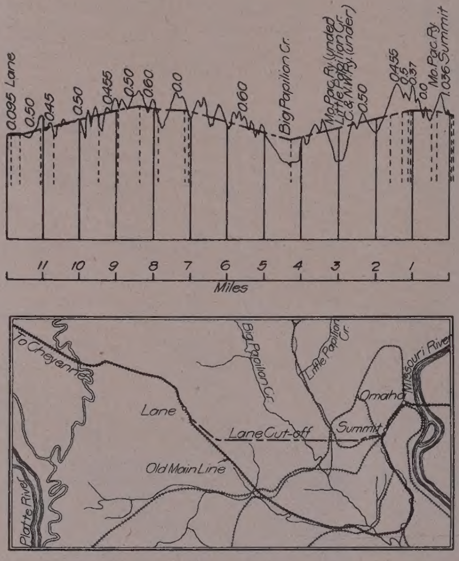
The improvements which have been made to the roadway and tracks of the Union Pacific Railroad since the latter came under the present management have involved the most complete reconstruction of a trunk line that has been undertaken heretofore in this country in the same length of time. A great volume of this work was done between the years 1901 and 1905, inclusive, but the most apparent results have been obtained during the past two years. The recent work on the main line between Council Bluffs, Ia., and Green River, Wyo., in a distance of 827 miles, has embraced the construction of a large amount of second track, the replacement of existing bridge structures, the installation of a complete automatic block signal system and the extension of existing division and terminal trackage and shop facilities. Similar improvements have also been made west of Green River to Ogden, and the capacity of the entire system has, in fact, been greatly increased. When the improvements already undertaken on the main line, together with other work under way on the Southern Pacific Railway, are completed, it is expected that the Union Pacific and Southern Pacific Railroads, with their connections at Omaha and Chicago, can still further reduce the time from ocean to ocean by some hours.

Starting at the Union Depot in Omaha, four new main line tracks have just recently been placed in service for a distance of 3 miles. Two of these tracks are for through passenger and freight traffic and the other two for the local business in and out of extensive switch yards which are being built in South Omaha. The two through main line tracks leave the two local tracks at the end of the four-track section and pass over what is known as the Lane Cut-off, which is the most heroic feature of the Union Pacific improvements that has been undertaken.

The original location from the eastern end of this cut-off made a wide detour to the south before starting west, in order to avoid a stretch of extremely rough, broken country formed by the watersheds of several small streams which flow generally from north to south. The distance across this rough country in a direct east and west line between the connecting points on the old main line with the Lane Cut-off is 11.64 miles, while the distance around the main line between the points is considerably greater. The existing traffic conditions rendered the elimination of this large amount of extra distance particularly imperative, although the air line route involved exceedingly heavy construction. Notwithstanding these conditions, the construction of a double-track cut-off was started in December, 1905, and will be ready for operation during the coming spring.

The cut-off has a total length of 11.64 miles and produces a saving of 8.94 miles in a distance of 20.58 miles between connecting points on the old main line. The maximum eastbound grade on the cut-off is 26.4 ft. per mile, and westbound is 31.7 ft. per mile, as compared with 42.2 ft. and 41.7 ft., respectively, on the old line. The maximum degree of curvature on both lines is 3 deg., although the total curvature on the new line is only 163 deg. and 44 min., as compared with a total of 407 deg. 12 min. on the old line. The new line has one tangent 7½ miles in length, with three curves at the east end and two at the west end.

The excavation for the cut-off was all in earth, and involved an estimated total of nearly 3,500,000 cu. yd. All of this material was utilized in making the embankments required to cross the wide, deep valleys between the hills, about 4,000,000 cu. yd. of embankments being built. The roadway in excavation has 1½ to 1 side slopes and a minimum width of 30 ft.; the embankments have a minimum width of 35 ft. and 1½ to 1 side slopes. These dimensions are the standards of the Union Pacific for double-track construction. The tracks are to be laid with 90-lb. rails on tie plates, treated ties of Oregon and Southern pine being used. These are also the standards for the entire main line, on which treated ties are used for all new work and renewals, except in a few instances where untreated Oregon fir has been used. In nearly all cases, 7 x 9 in. by 8 ft. sawed ties are employed on main line work.



Map and Profile of the Lane Cut-Off.

The heaviest grading on the cut-off is about a mile from the east end of the new work, where a cut with a maximum depth of 87.5 ft., a width of 437 ft., and a total length of 5,200 ft. was required. This single cut involved close to 2,000,000 cu. yd. of excavation. The necessary width of the cut at the top was increased from 304 ft. to 437 ft., in order to obtain material for the heavy fills to the west. The excavation was made with steam shovels with 2½ and 5 yd. dippers, and the material hauled out in standard-gauge flat and side-dump cars, to make a 1,275,000 cu. yd. fill over the Little Papillion Creek, half a mile to the west, and also in a 1,500,000 cu. yd. fill over the Big Papillion Creek, a mile still further west.

The fills over these two creeks were made under unusual difficulties, owing to the conditions encountered. At the point where the line crosses the Little Papillion Creek the valley of the latter has a total width of only 3,100 ft., and the tracks are at an extreme height of 96 ft. above the original ground surface. The valley of the Big Papillion Creek is about 400 ft. more than a mile in width, and is crossed on a fill with a maximum height of 65 ft. Both of these long, high fills for the double-track line were made from temporary timber trestles, built to carry standard-gauge equipment. Material was dumped from the cars on the trestle directly to place on both sides of the trestle, the embankments being built in successive layers extending across the valley. Notwithstanding the fact that this work was handled with special care, the trestles were pushed badly out of line and much extra filling was required, due to the instability of the alluvial soil which makes up the bottom of both valleys to a great depth. This instability resulted in several disastrous slides from the fills, the original soil being pushed up considerably for some distance from the toe of the slopes. These slides were finally avoided by building berm fills against both sides of each main embankment. In the Little Papillion Creek fill these berm fills were made 50 ft. wide on top and 20 ft. high, and for the Big Papillion fill, 30 ft. wide on top and 12 ft. high, side slopes of 1½ to 1 being used in both cases. Although these berm fills greatly relieved the danger from slides, a section of the Big Papillion fill involving over 40,000 cu. yd. of material slipped from place after the side fills had been built. In this instance, the original ground under the berm fill appeared to be pushed out of place, as an upheaval occurred in the bottom of the valley outside the berm.

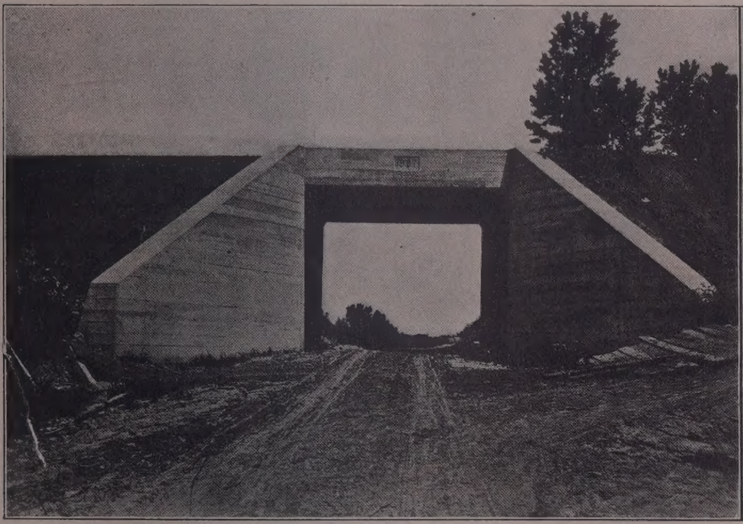
Temporary Timber Trestle used in Making Fill across the Valley of Little Papillion Creek.

The tracks are carried over the waterway of Little Papillion Creek on a deck plate-girder viaduct, with 40-ft. towers and one 100-ft. and three 80-ft. spans, the total length of this bridge being 460 ft. The legs of the towers are each carried by a concrete footing built on pile foundations, 40-ft. piles being used. Since the embankment will doubtless still settle to considerable extent, the ends of the viaduct will be supported on temporary pile piers until this settlement ceases, when concrete abutments will be built. The end embankments are expected to take, meanwhile, a slope of about 1½ to 1 and will thus extend to the base of the first tower at each end. The footings for the four legs of these end towers were therefore built on a continuous flat slab of concrete and the two footings on each side braced together by a vertical slab of reinforced concrete, in order to resist the resulting thrust from the fill.

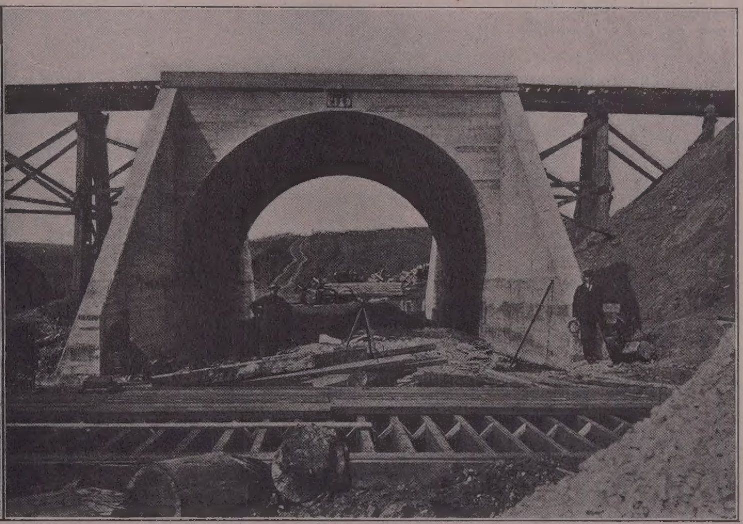
The soil conditions are so uncertain at the crossing of the Big Papillion Creek that the tracks will be carried on a timber trestle at this point until the embankment has settled. The intention is, however, to make this crossing on a structure similar to the one over the Little Papillion.

West of the Big Papillion Creek the line follows across the top of the country, with a series of heavy cuts. Hell Creek, 2½ miles to the west, is crossed on a 340,000 cu. yd. fill containing two 20-ft. concrete arches, one for the waterway and the other for an undergrade highway crossing. The barrel of the waterway arch is 148 ft. long, and was originally designed with footings 10 ft. wide on pile foundations. Such soft material was encountered in the excavation, however, that it was considered that the weight of the embankment might result in the bed of the creek being pushed up inside the arch, so a slab of reinforced concrete was placed across between the footings to prevent this action. The foundation piles for this arch were in 20-ft. and 40-ft. lengths, over 24,000 lineal feet of piling being required.

Several other structures were also required in building the Lane Cut-off. The Omaha Bridge & Terminal Ry., on which the Illinois Central R.R. enters Omaha, and the Chicago & Northwestern Ry. are each crossed once, while the Missouri Pacific Ry. is crossed twice. All of these crossings are made overhead, on steel viaducts, one of the Missouri Pacific crossings being included in the viaduct over the Little Papillion Creek. The other crossing of that railroad and the crossing of the Omaha Bridge & Terminal Ry. are made on a single structure consisting of a double-track 105-ft. pony truss span with two double-track 80-ft. plate girder spans at the east end. The Chicago & Northwestern R.R. is crossed on a 135-ft. through riveted-truss span, with a 60-ft. deck plate-girder span at each end. Most of the remaining bridges and culverts are of concrete, the larger structures being reinforced. Cast iron pipe was used for small waterway openings. All streets and highways, except one, will cross the cut-off overhead, or be carried underneath. Where sufficient headroom was available, undergrade highway crossings are carried in 20-ft. concrete arches. Otherwise, flat-top reinforced concrete structures, providing a clear width of 18 ft., and a clear height of 14 ft. for the roadway, were built. Advantage was taken of every opportunity to eliminate a grade crossing, there being but one such crossing on the entire line, which is an unimportant highway crossing.



Typical Flat-Top Highway Crossing.



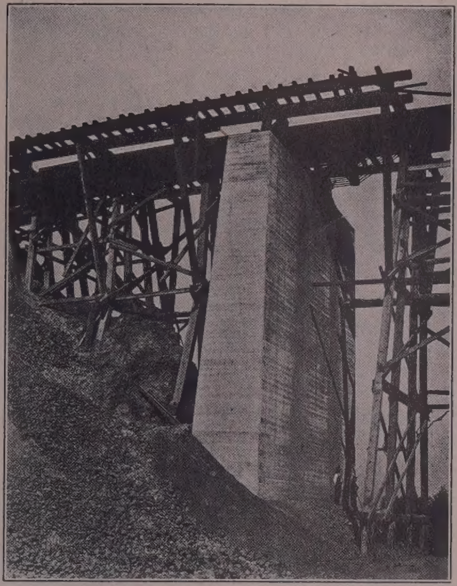
Typical 30-Foot Span Concrete Arch.

The contract for the grading and masonry work on the cut-off was carried on by the firm of Kilpatrick Brothers & Collins, of Beatrice, Neb. At one time the following plant was installed on the 9 miles of work: Thirteen standard-gauge locomotives, twelve narrow-gauge locomotives, seventy-two standard-gauge cars, including flats and 40-yd. Lawson dump cars, two Lidgerwood unloaders, three pile-driving outfits and equipment for four masonry gangs, as well as additional auxiliary plant. Complete construction camps and repair shops for the equipment were also maintained.

Double-track Work West of Lane.—From the end of the Lane Cut-off to Valley, in a distance of 11.3 miles, double tracking was finished in 1906, and trains are now also operated over double track to Sanberg, 15 miles west of Valley. A second track is laid for 30.6 miles from Ames to Benton and is ready for ballast. This is followed by about eight miles of finished double track, beyond which 17.8 miles of new second track is ready for ballasting, extending to the station of Silver Creek. The line between Silver Creek and Kearney has been double-tracked for over a year, so a continuous two-track main line will soon be in operation from Omaha to Kearney, a distance of 194 miles.

Beyond Kearney, in Nebraska, preparations are being made to add a second track by replacing existing bridge structures and making other changes, but no other work has been done.

A large amount of double-track main line is in operation in Wyoming, some of the second track having been laid for several years. The Archer Hill cut-off east of Cheyenne was among the first stretches of double track to be finished a distance of about 7 miles. This cut-off included much heavy grading and provides nearly 3 miles of line entirely distinct from the original location. West of Cheyenne, double track is in operation for 30 miles to Buford, part of which, a double-track section of 10 miles long, was built several years ago, much heavy grade reduction and realignment work having been done at that time. The construction of an entire new line from Buford to Laramie eliminated a large amount of curvature and greatly reduced the maximum grades on the climb from both the east and the west to Sherman Hill, just west of Cheyenne. Sherman tunnel is on this new line, being immediately east of Hermosa. In the 20 miles from Hermosa to Laramie both the old and new tracks are in service, being operated as double track, westbound trains using the old line and eastbound trains using the new line. The two tracks occupy entirely distinct locations; the westbound track is on the original location, the grade on which ran as high as 1.85 per cent.; the eastbound track is on a separate cut-off, built some time ago to avoid the heavy grades against eastbound traffic on the old line. The maximum grade on the new line is 43 ft. per mile, or about 0.8 per cent.



Pier 67 Feet High for Plate-Girder Span.

The grades are light from Laramie to Lookout, which are 25 miles apart, and a single track, with long passing sidings, is in service in this distance. Fifty miles of double track between Lookout and Hanna were finished in 1906. From Hanna to Rawlins, a distance of 40 miles, no second track has been laid, but in the next 43 miles to Wamsutter, work on a second track has been in progress during the past year and will be completed shortly, 18 miles being in operation at present.

From Wamsutter to Point of Rocks no work has been done in making a double-track line, although practically all the necessary location surveys have been completed. From Point of Rocks to Rock Springs double track is completed and in operation.

The provision of a second track across most of Nebraska involves comparatively light grading work, but a number of bridge structures and many waterway openings are required. Across Wyoming, on the other hand, the grading work necessary to provide for a second track is frequently exceedingly heavy, as the country is rough and broken. The numerous extensive cut-offs and the realignment work which have been done in that region have embraced a great volume of grading. All of the double tracking that has been done consequently necessitated much extensive construction work, which is fully justified, however, by the volume of traffic already existing.

The grades on the Union Pacific Railroad were always low, as compared with other lines in the same region, but are now remarkable since these various improvements have been completed. The line following the Platte River from Valley, 35 miles west of Omaha, to North Platte, permits a maximum grade of 0.5 per cent. against eastbound traffic and 0.6 per cent. against westbound traffic, between Omaha and Kearney. From Kearney, Nebraska, to Archer, Wyoming, a distance of 312 miles, the line ascends on an easy grade varying from 13 ft. to the mile to 37 ft. to the mile, the maximum grade being 0.7 per cent. westbound. From Archer to Cheyenne, 8 miles, the line descends westbound, the maximum grade being about 0.7 per cent. in both directions.

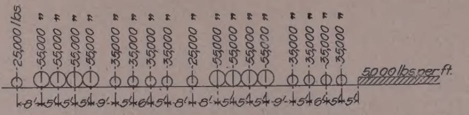
From Cheyenne, Wyoming, to Ogden, Utah, the maximum grade in both directions is 0.8 per cent., aside from a number of short stretches as follows: Cheyenne to Buford, 27 miles, maximum grade 1.55 per cent. westbound, the difference in elevation between these two points being nearly 2000 ft. Wahsatch to Castle Rock, 8.4 miles, maximum grade is 93 ft. to the mile, descending westbound. Castle Rock to Echo, 16.4 miles, the maximum grade is 60 ft. to the mile, descending westbound.

Echo to Morgan there are 15.5 miles of descending grade, the maximum being about 1 per cent. From Devil's Gate to Uintah, 5 miles, the line descends on a grade of 96 ft. to the mile. Aside from these five stretches the maximum grade in both directions is 43 ft. to the mile. With these low grades the double track that is already in service has greatly increased the capacity of the Union Pacific to handle traffic.

Bridge Structures.—Practically all of the single-track bridge structures are replaced by double-track permanent bridges before the second track is laid. This work is all done under traffic without interfering with train movements to any extent. The new double-track steel spans are erected at the side of the present structure. When ready the old bridge is then removed and the new one hauled into place. This work is greatly simplified by using heavy steel dolly trucks under all four corners of the structures, these trucks traveling on rails laid on shoring and falsework built up under the bridge.

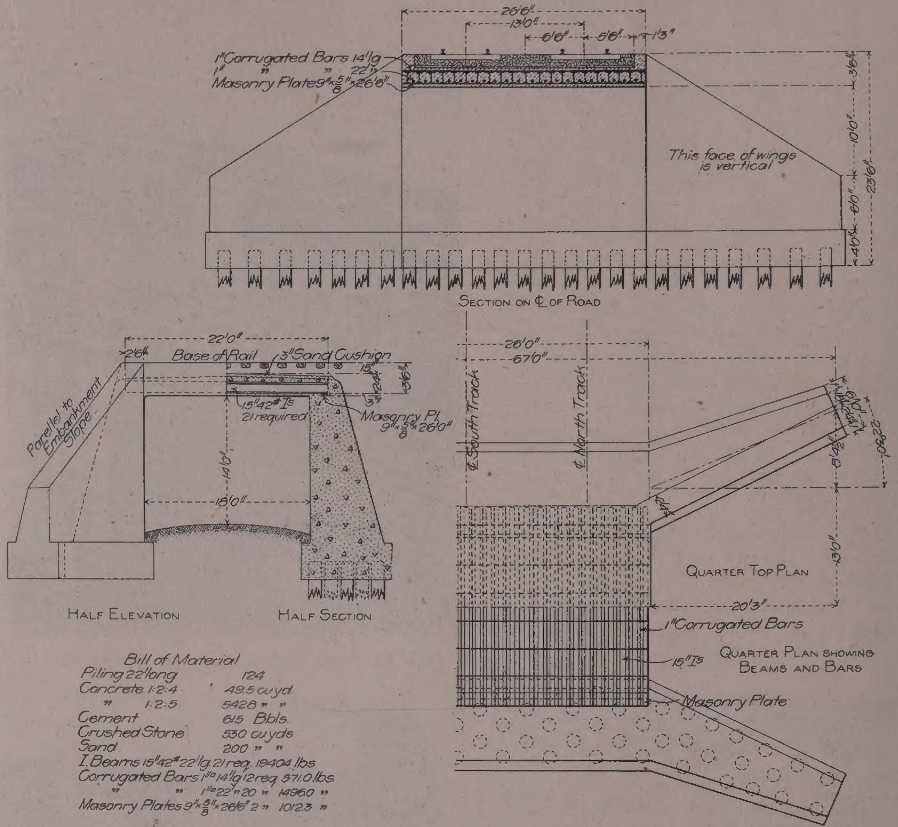
Various types of structures are used, depending on local conditions. All steel structures are proportioned to carry the following loads: The dead weight of the metal in the structure; a floor weighing 500 lb. per lineal foot for each track; for calculating stresses of trusses, three-quarters of the sum of these dead loads is considered to be applied at the panel points of the loaded chord and one-quarter at the panel point of the unloaded chord. The total weight of metal in the structures as built, together with the weight of the floor, is not permitted to exceed the dead load used in calculating stresses. The moving load allowed for each track consists of a train composed of two consolidation locomotives with weights distributed as in the accompanying diagram, followed by a uniformly distributed load of 5000 lb. per lineal foot.

The bridge over the Elkhorn River in eastern Nebraska is one of the larger structures replaced to provide for second track. This bridge has ten 65-ft. through plate girder double-track spans and one double-track through truss span 163 ft. long, all of which are on stone masonry piers and abutments. The piers and abutments were built and the superstructure erected under an average train movement of forty trains in both directions during twenty-four hours, almost without interfering with traffic, as has been done in all of the bridge renewal work.



Bridge Loading Diagram.

One of the principal other bridges on the main line which is being replaced by a heavier double-track structure is the one over the Loup River. The old bridge at this crossing has one 200-ft. and one 150-ft. Pegram truss, three 150-ft. Pratt trusses and six 75-ft. through plate-girder spans, all carried by stone masonry piers. The new double-track bridge will have the same length spans, and the old piers are being extended to carry the new structure. This masonry work is all on sand and clay, so necessitates a large amount of pile driving, all of which is being done without blocking the existing bridge. The superstructure of the latter will also be carried on a trestle while the new superstructure is being erected around it.

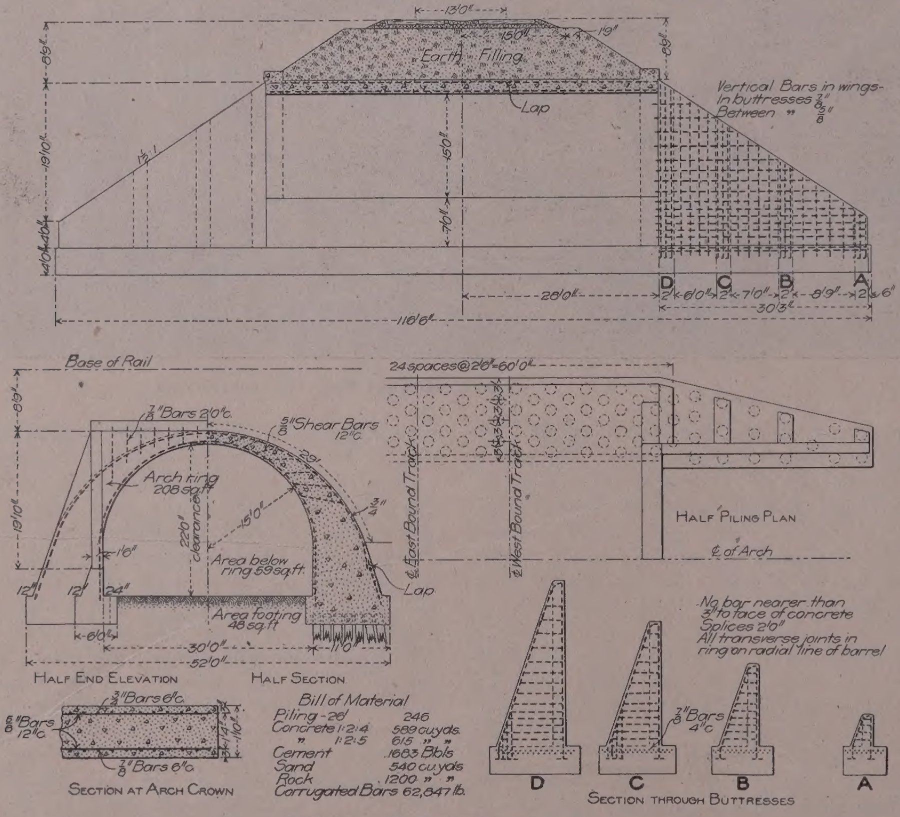


Bill of Material	
Piling 22' long	124
Concrete 1:2:4	49.5 cu yd.
" 1:2:5	5428 " "
Cement	615 Bbls.
Crushed Stone	530 cu yds
Sand	200 " "
I. Beams 15" 42# 22' lg. 21 req.	19404 lbs
Corrugated Bars 1" □ 14' lg 12 req.	571.0 lbs.
" " 1" □ 22' " 20 "	14960 "
Masonry Plates 9"×5/8"×26'6" 2 "	1012.3 "

Typical Flat-Top Concrete Span for Waterways and Highway Crossings.

For bridges and waterways where the headroom is limited and the span is between 15 and 50 ft., flat-top concrete structures are frequently employed. These concrete structures have solid floors reinforced with I-beams and corrugated bars, as shown in an accompanying illustration, and replace short steel spans, pile trestles, and so forth. They are constructed entirely without hindrance to traffic on the main line track. The abutments are first built with the track blocked up in place, then the slab is erected under the site of the new second track and after the latter is laid, traffic is shifted to this track until the remainder of the slab can be finished and both tracks placed in service.

The details of a typical concrete arch that has been adopted for use under high fills are shown in an accompanying illustration. This particular arch has a 30-ft. span and is for a highway crossing under the new cut-off in Omaha. Other structures of this kind that have been built are of the same general type, although much special designing had to be done in connection with the arches under the high fills on the Lane Cut-off.



Bill of Material	
Piling-26'	246
Concrete 1:2:4	589 cu. yds.
" 1:2:5	615 " "
Cement	1683 Bbls
Sand	540 cu. yds
Rock	1200 " "
Corrugated Bars	62,847 lb.

Details of 30-Foot Concrete Arch.

Automatic Block Signals.—Prior to Jan. 1, 1906, about 64 miles of the main line had been equipped with automatic block signals, leaving a total of 1,027 miles to be installed. The signal work authorized for 1906 and 1907 included the equipping of the entire main line from Council Bluffs, Iowa, to Ogden, Utah, a distance of 1,000 miles, with continuous automatic block signals of the semaphore type, controlled by electric track circuits. It also included the installation of similar signals between Kansas City and Topeka, Kan., a distance of 67 miles, and from Julesburg, Colo., where the trains to Denver leave the main line, to Denver, a distance of 197 miles. The Union Pacific now has in operation 834 miles of single-track automatic electric block signals and 356 miles of double-track automatic electric block signals.

The significance of the work in this line is better appreciated when it is understood that in September, 1906, there were only 6,827 miles of automatic block signals in use on all of the railroads in this country, according to the record of the Interstate Commerce Commission. The greatest mileage in operation on any one railroad at that time was on the Lehigh Valley R. R., which had 469 miles in service.

All signals of the semaphore type on the Union Pacific are operated by electric motors and are controlled by continuous track circuits, so the presence of a car, engine or train in any part of the block, an open switch, a broken rail, or a car not into clear on a side track in the block, will cause the signals at the entrance of the block to indicate "Stop" to approaching trains. The entire signal system is so designed that a failure of any part will cause the signals to indicate "Stop" in order that the derangement of any part of the apparatus will result in no danger. Failures of operation are, however, infrequent, being less than one in every 15,000 operations of the signals.

In addition to the regular automatic block signals over 300 electric distant switch signals were installed during the latter part of 1906 on parts of the system where it is not intended to install continuous block signals. These distant signals are designed to indicate any open switches in the main line.

Six interlocking plants have been installed at the ends of double track to protect trains entering or leaving single track. Arrangements are also being made to equip all the principal grade crossings with other railroads with interlocking plants of the most complete and modern design, seven crossings being already so equipped. Altogether twelve new interlocking plants have been installed since Jan. 1, 1906, and two old plants have been enlarged, the old manually operated machines being replaced with power machines of the latest type.

A number of automatic bells are also in operation, protecting highway crossings, and on 11 miles of single track, occurring in the middle of a long stretch of double track, the electric train staff system has been provided, permitting trains to be run entirely without train orders for this distance. None of the work is being installed by contract, material being purchased from the manufacturers and installed by the railroad company's own forces under the direction of the signal engineer.

The operation and maintenance of the signal system is also under the general direction of the signal engineer. The continuous automatic block system is divided into sections 10 miles in length with a man in charge of each section, each ten sections being under the supervision of a foreman; one man to charge the electric batteries is also provided to each ten sections. All of the foremen on each division report to a division supervisor, who report to the division superintendent.

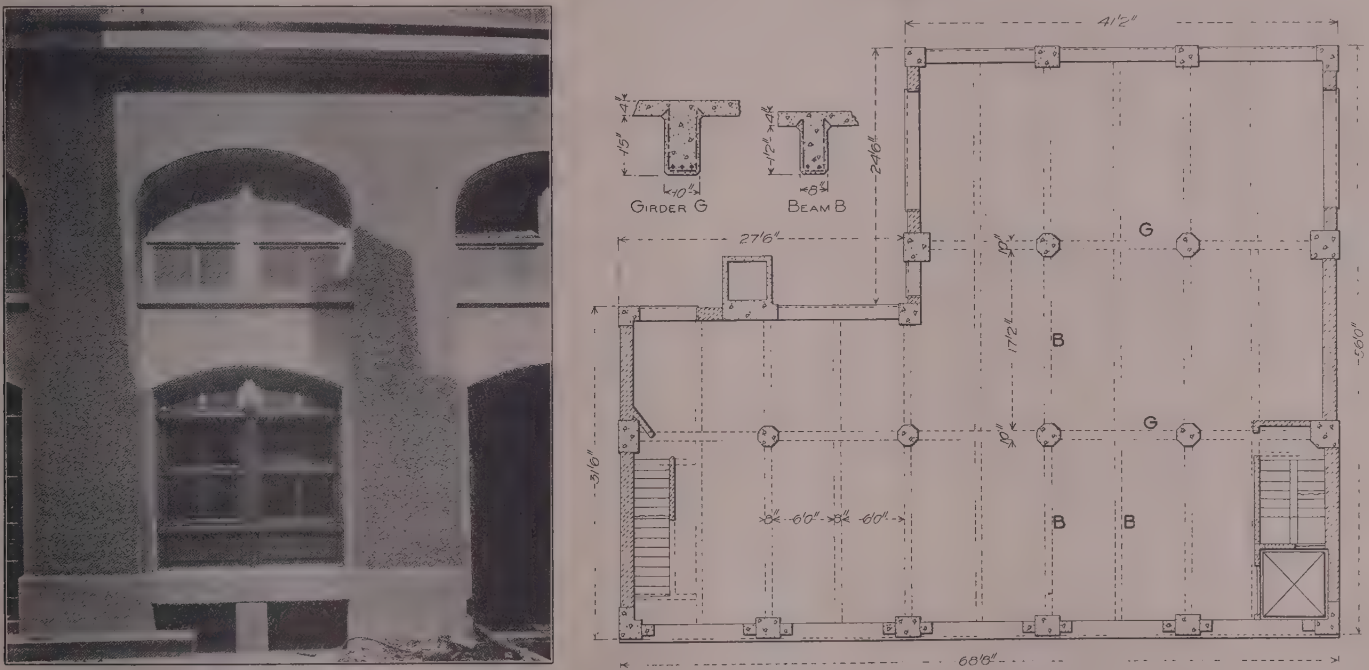
Extensive improvements to shop and terminal facilities have already been made and much additional work is under way or authorized. Several modern mechanically operated coaling stations are being installed, some of these being at new locations, while others replace old trestle gravity type structures.

A Novel Bridge and Spillway have been designed for the dam which is to be thrown across the valley of Wascana Creek, and is to carry Albert St., at Regina, Province of Saskatchewan, Canada. The dam, which is about 900 ft. long and 22 ft. high above the bottom of the reservoir, is an earth structure, with the downstream side retained by a reinforced concrete wall. The spillway and bridge are located at the center of the dam, the crest of the overflow being upstream from the bridge, a distance of 9 ft. 6 in. Wing walls built continuous with the bridge abutments run out beyond the ends of the overflow section, and the waterway beneath the bridge is a monolithic continuation of the spillway floor, extending across from abutment to abutment and downstream to the ends of the wing walls, the purpose being to render undermining by erosion impossible. A sluiceway for draining the reservoir will be built into the spillway section. The bridge has a span of 80 ft., and the overflow a similar length. The spillway, spillway floor and bridge will be built of reinforced concrete, the whole resting on piles.

A Ten-Story Building in Forty-Seven Working Days.

Construction work in the lower part of Manhattan, New York City, is ordinarily difficult to execute, and particularly so when the contract is a penalty-and-bonus one. An interesting example of how various problems occurring in the course of such a contract may be handled in reinforced concrete construction is afforded by the erection of the building of Rogers & Pyatt, manufacturers of varnishes, at 34 Fletcher St. This building was designed by Messrs. Ludlow & Valentine, the piling, excavating and foundations being put in by the Foundation Co. and the waterproofing by the T. New Construction Co., both working under the Turner Construction Co. of New York City, the general contractor for the building, who executed all the reinforced concrete work in it.

The location of the building on Fletcher St., a narrow alley scarcely 15 ft. in width, with sidewalks only 4½ ft. wide, but with traffic enough passing through so that the street could not be closed, was the first difficulty to be overcome. This made the receiving of material especially troublesome and the storage of anything whatever, or even the placing of a small shanty outside of the building line, out of the question, nor could a working platform of sufficient width to be of value be erected.



Finish on Street Front and Typical Floor Plan of Rogers & Pyatt Manufacturing Building.

The close proximity of the building to the East River made necessary the use of pile foundations, and the deep basement some 10 ft. below the tide level required careful waterproofing, continuous pumping while putting in the foundations, and ample reinforcement against upward water pressure. The installation of a boiler plant in the basement necessitated the construction of the basement and first floor in two sections, each section being at a different level, and in almost every story special provisions had to be made to accommodate the apparatus, vats, vents and piping required by the owner.

After the building was well under way the plans were changed from an eight-story to a ten-story structure, the floor loads were also changed, necessitating prompt action in securing additional steel and supplies. The desire of the owners for the greatest speed in erecting that was practicable called for careful planning, not only of the concrete work, but also of all sub-contract work, such as fire escape, doors, windows, skylights and painting, so that the various kinds of work might go on simultaneously and at the same time economically.

The building is somewhat irregular in plan, having a street frontage of 68 ft. 8 in. and a maximum depth of 56 ft., the plan above the first floor being a rectangle with one quarter omitted.

As the work was commenced in winter, it was at once foreseen that after the excavation, piling, waterproofing and the foundation walls were in place it would still be too early in the season to get trap rock down the Hudson River, and it would be necessary to haul stone at heavy expense from Jersey quarries or from cars placed at uptown terminals, unless a supply could be procured to last over the close of navigation. Accordingly a bulkhead on the East River was rented and ¾-in. trap rock sufficient to carry up the building to the sixth floor was placed upon it.

The excavating and piling were started early in January. Continuous rows of piles were driven on the outside line of the property, the spacing varying with the loads to be carried, double lines being driven under all wall columns. From nine to sixteen piles were driven under each interior column, and piles were driven for the engine foundations. Piles were cut off at a depth of from 8 to 16 ft. below the curb level, depending upon the depth of the basement floors. A continuous concrete cap reinforced with twisted steel rods was built on the outside line of piles, with similar caps over all interior piles, and a 3-in. layer of concrete was laid over the entire basement floor. Four-inch brick walls were then carried up to the curb level on the outside lines of the property. Against this five-ply felt coated with tar was applied which was carried continuously down over the concrete cap, over all the interior footings, over the 3-in. layer of concrete previously mentioned and against the vertical offsets in the floor. An electric pump continuously operated prevented the displacement of the waterproofing while being applied and was not abandoned until the basement floor had been entirely put in and heavily loaded with material. The main basement wall and exterior columns were then built on the inside of the waterproofing, and the basement floor, 9 in. thick on the upper level and 21 in. on the lower, was laid. This floor, as stated before, was reinforced against upward water pressure; reverse beams containing from three to five ¾-in. square twisted bars were extended between all columns and ½-in. square twisted bars were placed in the upper part of the floor slab to transfer the pressure to the columns and walls. The above work was finally completed on April 21, 1907, and the structural part of the work was commenced.

A Ransome concrete mixer had been installed in the basement connected with the Lidgerwood drum hoist, both machines being in the center of the building and requiring the omission of one panel of the floor slab in each floor. Two sets of floor and column forms were made up in a yard some distance from the work, but close to a lumber yard where power saws and other machinery made the cost of constructing the forms economical. They were hauled to the site in the exact order they were needed and set in place immediately. The greater part of the trap rock which had been stored on the bulkhead was placed in the basement to load the floor properly and be ready for use. Sand and cement were delivered to the building by trucks. Any rubbish or waste matter was removed at once by trucks, as the cramped quarters allowed no storage room for débris.

The forms for the first floor were set on April 22 and each floor was completed in 4½ working days thereafter, the roof being poured on June 27, or in 47 working days after the work began on the erection of the first-story columns. By the use of two sets of forms no centers were struck in less than five days and posting was kept in place under all beams and girders for fifteen or twenty days.

In all cases when the weather permitted the floor finish was put on at the same time as the floor slab, but the work was not delayed when the weather was inclement; in that case the rough slab was put down and the finish applied afterward and thoroughly bonded to the slab by the Ransome method. As it was necessary to set forms upon freshly finished floors, building paper was laid over each floor as soon as the finish had hardened. This, of course, could be used but once, but prevented any grout or concrete from the upper floors from sticking to the finish and made the cleaning up very much easier. The stairways were carried up close behind the floors and also the concrete curtain walls on the front elevation; all rear and side walls were built in brick.

As soon as the first two floors were in place and the speed of erection could be definitely fixed, a complete working schedule was made up for all work connected with the building. The various sub-contractors were consulted and notified just when the building would be ready for their material, and when it must be delivered and set in place. For instance, a date was set for starting the brick curtain walls of each floor. The iron contractor was informed that all fire-escape brackets must be on hand to be built in, and the window contractor that the window frames must be delivered. Similar dates were set for starting the elevator and stair partitions, and all door frames, with their necessary bolts, had to be in readiness for setting. The door frames were 7-in. channel irons and were shipped direct from the mill cut to the exact length, in this way avoiding all waste. They were punched and assembled on the job. The sizes of the door openings were thus accurately determined before setting, which permitted the fire doors and two section elevator doors to be built without requiring a measurement of each opening. The doors were then hung as fast as partitions were in place. The stairways were carried up so promptly that measurements could be taken for the stair railing in ample time to procure what special fittings were required. Bolts and anchors were set in the forms for attaching the large ornamental brackets on the façade, and also for the framework carrying the copper cornice. In each floor diagrams were furnished by the owner's engineers, showing the proposed arrangement of piping and the like, and threaded sockets were set in the floor slabs to attach hangers, thus doing away with all future drilling. Openings were left for plumbing lines, vents, acid conveyors and other pipes, and holes were left in all beams and girders close up under the floor slab to allow the installation of electric conduits, as it was not possible to decide on the lighting layout until later.

Measurements were taken for all skylights and ventilators while the roof forms were still in place, so as to give all the time possible for their manufacture. As soon as the roof was poured and material for the brick masons had been placed on different floors, dry materials for closing the openings left for the hoist were also hoisted, the hoist was dismantled and the omitted floor slabs set in place, well bonded to the balance of the floor. All interior surfaces were given a coat of cold-water paint and the front elevation tool-dressed for the lower two stories, as shown in an accompanying picture, and treated with La Farge cement and white sand on the upper portion.

The window frames and doors, stair rails and other iron work were given one coat of paint before being erected and the finish coat put on after they had been put in place.

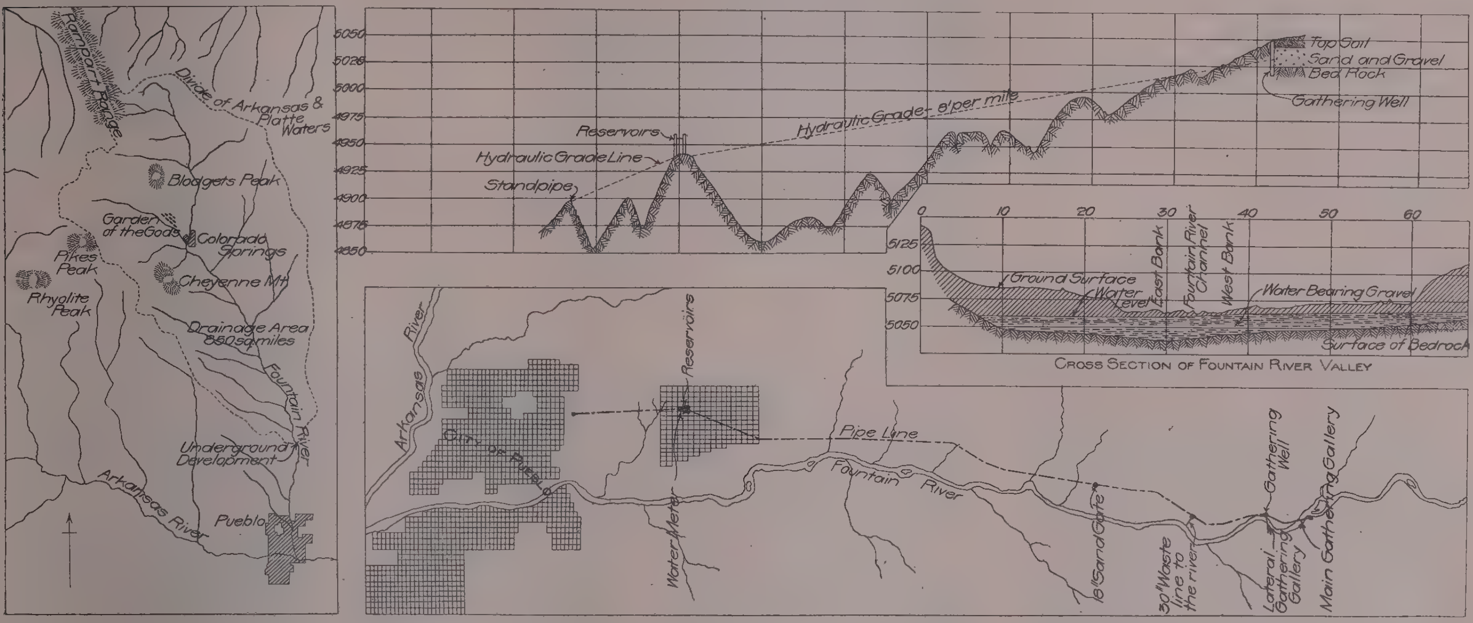
By careful attention to the schedule prepared and by insisting and seeing to it that all subcontractors lived up to the specified date as to the deliveries, the job was finished and turned over to the owners on Aug. 12, 1907; in other words, in 113 calendar days after the first formwork was undertaken. This rapid work finished the job 34 days before the time allowed.

The structural details of the building are shown in the accompanying typical floor plan. The reinforcement used consisted of square cold-twisted Ransome bars with proper stirrups and connections. In pouring the floor the beams, girders and slabs were all poured at the same time, thus doing away with any shrinkage cracks or shear planes between the slabs and the girders and beams. The interior columns were octagonal in shape, varying from 32 in. in diameter in the basement to 15 in. in the ninth story, and to square columns 10 in. on a side in the tenth story. The interior columns were reinforced vertically by 1¼-in. round rods and laterally with 7/16-in. wire wound in a spiral of 29 in. diameter to a pitch of 1¾ in. This was the heaviest of the column reinforcing. The vertical steel was made continuous from story to story by means of threaded ends and sleeve nuts. The front curtain walls were 16 in. in thickness in the lower and 12 in. in the upper stories and were reinforced with ½-in. square twisted bars. The rear and side walls were of brick of the same thickness as the front curtain walls. All windows were fireproof construction, built of hollow metal frames and glazed with ¼-in. ribbed wire-glass. They were set after the curtain walls were built and were grouted in place, all mullions and sills being poured after the windows were set. Partitions were constructed of hollow tile with channel iron frames set in place during erection. All doors were of fireproof construction; the front entrance and office doors were kalamein covered. All stairway and partition entrances were protected by the standard tin-covered fire doors and the elevator openings were fitted with automatic closing two-section tin-covered doors. Rolling steel shutters inclose the shipping entrance.

There are two stairways and one elevator in the building, the stairs being of concrete fitted with pipe railing. Leanto skylights glazed with wire-glass extended along the rear of the building over an extension to the first floor, and smaller skylights and ventilators were set in the roof, which was covered with standard tar and gravel roofing.

A Building without Windows has been erected at St. Louis for the E. B. Lewis Publishing Co. It is built with solid walls, there being only two openings, for a door in the front and one in the rear of the building. The structure, which is known as the National Daily Building, measures 68 x 170 ft. in plan, is 58 ft. high, and is entirely lighted from a skylight in the roof, the main part of the building forming one large room. The building is of reinforced concrete, finished exteriorly with a 2-in. marble facing. A copper cornice, 6 ft. high, backed with a parapet wall of concrete, 1 ft. thick, runs around the top of the building and forms a striking contrast to the white marble surface. The roof is carried upon steel trusses, of 65-ft. span, which rest on concrete piers built into the walls. Curtain walls are built between the piers, being single and 12 in. thick in the lower part, and double, with an air space between two 6-in. walls, in the upper portion. The air space is divided at horizontal intervals of 3 ft. by solid vertical cross partitions of concrete. A reinforced concrete lintel, 8 ft. above the level of the first floor, carries the double wall between the piers and allows of a recess due to the greater thickness of the upper wall. The basement is lighted partly by area windows. The plain and reinforced concrete work was done by the P. M. Bruner Granitoid Co., of St. Louis, and Mr. C. Herbert Chivers was the architect.

A NOTABLE GROUND-WATER DEVELOPMENT AT PUEBLO, COLO.



Watershed of Fountain River, Plan and Profile of Flow Line and Section of River Valley.

Pueblo, Colo., is a manufacturing center of considerable importance, situated slightly to the south of the central part of that state, on the eastern slope of the Rocky Mountains. The city is built along both banks of the Arkansas River, which flows generally eastward at this point, with the population of approximately 50,000 about equally divided between the two parts of the city. The extensive steel works of the Colorado Fuel & Iron Co., which are the principal industry, are on the south side of the river, two miles from the business district on the north side of the river.

Two separate municipal water-works systems are in service, one for each side of the city, the steel works having a private, separate system. The water for both public systems was formerly obtained directly from the Arkansas River and pumped into the distribution mains without purification. As this river is subject to dangerous contamination from the communities on its catchment area above Pueblo, and as its water is frequently quite turbid for considerable periods, the supply has been far from satisfactory. The local conditions, however, render the provision of any other adequate supply of good water a very momentous proposition. The rainfall in this region is only between 13 and 14 in. a year, so most of the streams are dry during a major portion of the time; such surface flow as does exist is fully appropriated for irrigation purposes. At the same time, water from wells within the city limits, and, in fact, in the entire region is more or less alkaline, depending on the location and depth of the wells. Furthermore, water from surface wells within the city, even if available in sufficient quantity, would be subject to dangerous contamination. A supply from wells, consequently, cannot be obtained. A source of supply could have been found at one time in the foot hills of the mountains, 30 miles north and east of Pueblo. Such a supply is now out of reach of the community, however, since all the suitable and available water from this source is appropriated, and in order to procure water from any stream in the foothills these rights would have to be condemned and purchased. The expense of this condemnation and purchase would be very large, and added to it would be the cost of bringing the water to the city.

Some unusual means of development therefore had to be undertaken to secure the requisite amount of desirable water. Accordingly, such a development has been made about 14 miles north of Pueblo in the underground flow in the valley of the Fountain River, which empties into the Arkansas River just below Pueblo. Water is now being supplied from this development to the distribution system for the north side of the city. No provision has been made as yet, however, to furnish the south side of the city with water from the development, although an adequate quantity is available for all purposes.

The Fountain River has its source along the eastern base of the Rocky Mountains, in the vicinity of Pike's Peak, the watershed above the development being about 850 square miles. Like most streams which have head-waters along the eastern slope of the mountains, this river is subject to extreme variations of flow. Three or four times each summer large surface floods occur, caused by sudden, heavy rains over the watershed. These floods vary in volume, but at times are of such extent as to overflow the banks of the main channel of the river and to spread to a depth of 4 to 5 ft. over the entire first bottom of the river valley, which is half a mile or more in width. As the average fall in the river is about 30 ft. to the mile, the run-off is very rapid. Owing to this rapid run-off also, which quickly carries away the melting snow from the mountains, and to the scanty rainfall over most of the catchment area, the flow is generally small and the stream is frequently dry on the surface for considerable periods.

The topography of the country and the nature of the formations in the river valley are such, nevertheless, that an underflow of remarkable character occurs. A cross-section of the valley, shown in one of the accompanying illustrations, indicates the general conditions existing. The valley is usually from a mile to a mile and a half in width, and is underlaid by bed rock, which rises at the sides in such a manner as to form a continuous basin below the level of the valley. Generally speaking, the surface of the bed rock slopes from the hills on both sides toward a well defined depression near the middle of the valley. At the same time, this depression does not conform with the channel of the river, as the bed of the latter is shifting sand, with the result that its channel is often changed. The surface of the bed rock is also naturally irregular, but at no point does the rock appear above the ground. Over the bed rock is a continuous stratum of coarse, water-bearing gravel, which has an average depth of 16 ft. for a width of 6,000 ft. at the point where the development has been made. This gravel is overlaid in turn by an alluvial deposit and adobe soil of varying depth.

The deep stratum of water-bearing sub-surface gravel is in evidence in the whole 40 miles of the river above the development, and outcrops in the mountains, where it receives its water from the practically perennial snow there. As is common with many streams in the Western part of the country, it is believed that this water does not leave the gravel again after entering it at the mountains, and is thus independent of the surface flow. The supply is therefore contained in the long, underground reservoir that lies at a slope roughly corresponding to the grade of 30 ft. to the mile in the river, with the result that the flow through the gravel is comparatively rapid. It is probable, of course, that the supply is momentarily augmented from the surface flow during excessive floods, but the conditions are such that the influence of the surface water on the underground flow is of short duration.

The works which have been built to develop this underground flow consist of gathering galleries, laid just above the bed rock in the bottom of the water-bearing gravel. These galleries converge at a gathering well, from which a flow line has been laid for 10 miles to two distributing reservoir basins on a hill above the city, and about 2 miles distant from the northerly limits of the latter; a pipe line connects these basins with the distribution mains of the north-side water works. The flow through the entire system is by gravity, the location of the basins rendering available 105 lb. pressure at the hydrants in the business district, and satisfactory operating pressures at the other points in the city.

After preliminary tests at the site of the development had shown the existence of a large volume of water in the stratum of gravel over the bed rock, an extensive investigation was conducted to determine the best location for the gathering galleries. Local topographical conditions defined within certain limits the most feasible area in which to place the galleries, so the investigations were confined to this area. Some thirty odd 6-in. test wells, cased with iron pipes, were driven to obtain samples of the gravel for mechanical analysis, and to show the position of the ground-water level. The results shown by these wells determined the sub-surface strata conditions already outlined. These results checked soundings, which had previously been carried to bed rock at intervals of 100 ft. along the proposed sites of the galleries, and at various other points. One peculiar feature of the underground flow thus determined was that the ground-water level has a slope from both sides of the valley toward the depression in the bed rock of as much as 7 ft. in 3,000 ft., which is a strong indication that this flow is independent of the stream.

Mechanical analyses were made of eight samples of the gravel from the test well borings to determine the character of this gravel and the percentage of voids in it. The character of the two extreme samples tested is given in table 1. Tests of these same eight samples to determine the percentage of the voids showed a minimum of 28 per cent. in one sample, and a maximum of 37½ per cent. in another, so the water-carrying capacity of the gravel is large.

Table 1.—Character of Two Extreme Samples of Gravel.

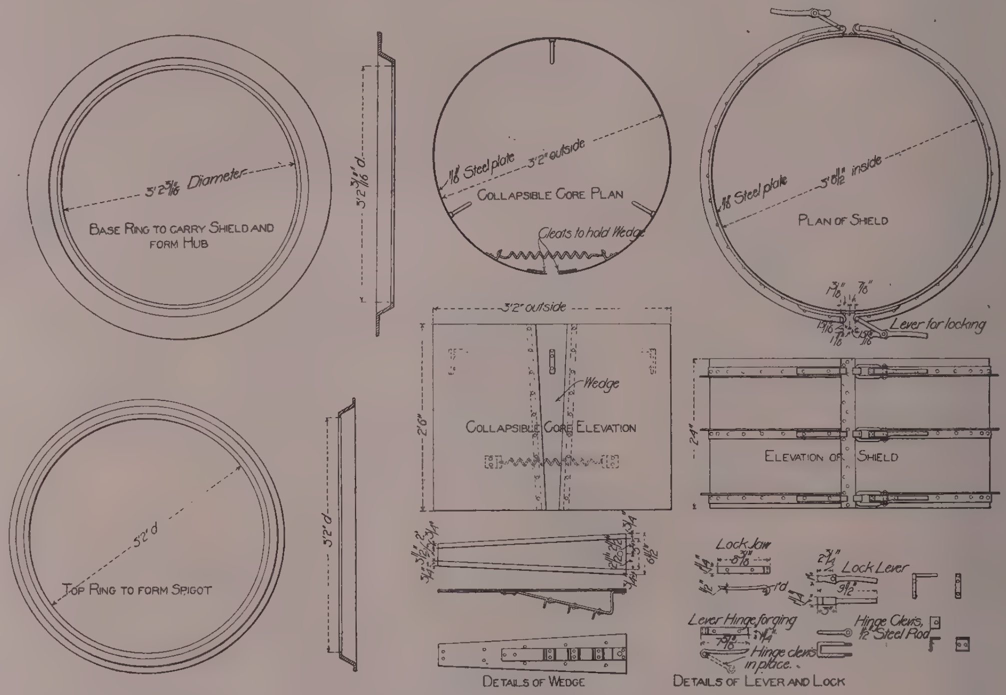
Mesh of Sieve.	Sample 1. Per cent. retained.	Sample 2. Per cent retained.
Coarser than No. 8 mesh	47.15	17.86
Finer than No. 8 and coarser than No. 12 mesh	49.52	17.88
Finer than No. 12 and coarser than No. 30 mesh	39.81	23.47
Finer than No. 30 and coarser than No. 50 mesh	10.71	3.53
Finer than No. 50 and coarser than No. 100 mesh	12.06	2.23

The ultimate plan for the gathering galleries contemplates a herringbone system, with a main gallery extending generally up and down stream, following the depression in the bed rock, and with lateral galleries at regular intervals on both sides of this main one. It is planned that these lateral galleries will have a slight up-stream inclination to increase their grade. Thus far only the main gallery and one lateral have been built, as a more than adequate supply is obtained from them. Manholes with branch connections have been placed on the main gallery, though, so additional laterals may be connected readily.

The two galleries which have been built, are of hub and spigot reinforced concrete pipe, made in 2-ft. sections and laid with a space of ⅜ to ½ in. between the joints. The main gallery is on a uniform grade of 4.73 ft. per 1,000 ft. and has a total length of 3,300 ft., the first 1,250 ft. from the gathering well being 38-in., and the remainder 30-in. pipe. The lateral extends from the gathering well diagonally up-stream for 1400 ft. on a grade of 2.15 ft. per 1000 ft., and is of 30-in. concrete pipe. The outlet from the gathering well is built of 38-in. hub and spigot concrete pipe, also in 2-ft. lengths, which is laid with tight joints. This outlet forms the upper end of the 10-mile flow line leading to the reservoirs, the first 10,350 ft. of the line being built of concrete pipe. A waste-way chamber is inserted in the flow line at a point 6,550 ft. from the gathering well, and a 30-in. waste line, 1,400 ft. long, and also of hub and spigot concrete pipe, is extended from this chamber to the river. Two valves are provided in the waste chamber, one on the outgoing flow line to the reservoir, and one on the waste line. The connections of the gathering galleries to the gathering well are also each provided with a valve. With this arrangement the section of the flow line between the gathering well and the waste chamber can be drained, and the supply can be cut off from the portion of the flow line below the waste chamber.

Concrete Pipe.—More than 18,000 linear feet of hub and spigot concrete pipe, in 30 and 38-in. sizes, was made in connection with the project. This pipe was all in 2-ft. lengths, the shell of the 38-in. size being 3¼ in., and that of the 30-in. size, 2½ in. thick. The concrete was made in the proportions of one part Iola Portland cement to 4½, or 5 parts of gravel obtained from the river, depending on the percentage of voids in the gravel. The latter was of excellent character for the purpose, varying from sand to stone that would pass a ¾-in. screen. The concrete was all mixed by hand, and was thoroughly hand-tamped in the molds in which the pipes were cast. The resulting pipe was of excellent quality, as was determined by a number of tests made shortly after the manufacture of the pipe was commenced.

Each section tested was first placed in a hole and imbedded, nearly up to the springing line, in sand. A platform, supported by four saddles made of 1½ in. oak, and equally spaced on the section, so as to fit closely across the top of the pipe, from springing line to springing line, was then loaded with cement in sacks until the pipe failed, or at least showed signs of failure, since it was impossible to destroy some sections with the loads available. After the first two sections had been tested in this manner it was evident that the saddles fitted so closely at the springing lines that the pipe in crushing had no opportunity to spread at these points, a condition which would scarcely have obtained in actual service. The under edges of the saddles were, therefore, cut away until they did not rest on the pipe for about 4 in. above the springing line on each side. About twenty plain and reinforced sections were then tested to determine their safe and ultimate carrying capacities. The pipe, when tested, was from 15 to 26 days old. Rings of round ⅜-in. iron rods, barbed wire, and annealed round wire were used in the reinforced sections tested. The ⅜-in. rods gave the best results, but were too expensive for the purpose. The annealed round wire produced better results than the barbed wire, and as the pipe reinforced with the round wire had sufficient strength, this wire was accordingly used in all of the pipe that was reinforced. The results of the tests were fairly uniform, and demonstrated that pipe reinforced with seven No. 5 wires in each 2-ft. section could safely be used in the trenches over 12 ft. deep; and that plain pipe had ample strength for the balance of the work. The section of the flow line in which concrete pipe was used is also built of plain pipe, the maximum head on this section being 7 ft. This section of the line has been perfectly satisfactory in service.



Details of Mold for 38-Inch Concrete Pipe.

The concrete pipes were made at a cost below that of any other satisfactory material that could be delivered at the work. This low cost was largely due to the fact that the aggregate for the concrete in the pipe was gravel obtained adjacent to the work, so freight had to be paid on the cement only, and the amount of hauling from the railroad was greatly reduced. Another very considerable factor in the reduction of the cost of the manufacture of the pipes was a special mold which was developed in connection with the work.

The details of the mold for the 38-in. pipe are shown in two accompanying illustrations, the molds for the 30-in. pipe being exactly similar. This mold consists essentially of a collapsible inner core and an outer shell, or shield, built in two parts. The core and shield are both made of No. 10 guage steel plates, the shield for the 30-in. mold being reinforced with two 1-in. angles, and the one for the 38-in. mold with three 1-in. angles. In casting a pipe the core, which is 6-in. longer than the shield, is placed upright, with the lower end inside a cast iron ring that fits around it. The core is made in one piece, with a vertical opening permitting it to be forced tightly against the base ring by a steel-plate wedge. This wedge is made to fit into a cleat on each side of the opening, in order to produce a joint that will not cause any deformations on the inner surface of the pipe. The two parts of the outer shield are fastened together with lock levers of very simple design, these levers and locks being attached to the reinforcing angles. The shield is placed on the base ring, the latter being made so it forms the hub of the pipe.

When a mold has been set up, the concrete is placed in it in about 4-in. layers, and each layer thoroughly tamped. In order to insure good results in tamping it has been found that three men were required to a mold. The concrete is made dry enough so that water would flush to the surface only under thorough tamping, and requires considerable skill to mix properly. After filling a mold to the top of the shield, a ring of sheet steel, built as a section of an inverted circular hopper, is laid on the shield. This ring is of such size that a space remains between it and the core, the latter projecting above the top of the shield, so concrete can be shoveled into this space and built up to form the spigot end of the pipe. When a sufficient amount of the concrete for the spigot has thus been placed, the light steel ring is removed and replaced by a heavy cast iron ring, with a cross section the same as that of the spigot of the pipe. This ring fits closely around the core, and by revolving it the spigot is easily and accurately formed. A gang of three molders could cast sixteen 2-ft. sections of 38-in. pipe and twenty 2-ft. sections of 30-in. pipe in this manner in 10 hr.

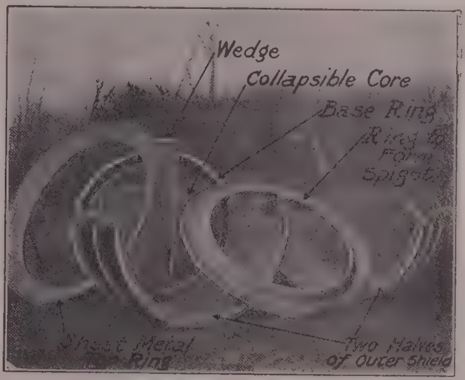
The dry mixture of concrete was required in order that the molds could be removed immediately after the pipe was cast. The pipe made in the manner described stood alone when perfectly green, without any signs of weakness. Each pipe was left on the base ring about 72 hr., depending on atmospheric and other conditions, before it was upended and the base ring removed. During this time the section was sprinkled continuously.

The first pipes were made at the river end of the 30-in. waste line, but soon after the work was started cold weather set in, so a 50 x 100-ft. frame warehouse, ceiled with corrugated sheet iron, was erected adjacent to the main gathering gallery, and the remainder of the pipe made in this warehouse during the winter. Sheet-iron stoves were installed to maintain the temperature in the building, and other precautions were observed to protect the new pipe from freezing.

The cost of the first pipe made was somewhat higher than the average, owing to the inexperience of the molders, and to other causes, but was at no time up to the cost of other material that could be used. The average cost of the plain pipe when made in the warehouse was very close to $1 a foot for the 38-in. size and 75 cents a foot for the 30-in. size. The cost of the reinforced pipe was increased over that of the plain practically by the cost of the reinforcing material, as the method by which the concrete was placed in 4-in. layers in making the plain pipe permitted the reinforcement to be inserted without added expense. The costs given include every expense, even to a proportionate charge for construction camp expenses, the watchman's salary, coal for heating the warehouse, and the labor required in rolling the pipes out of the warehouse. Laborers were paid $2 and a foreman $3 a day, the one foreman running the whole gang. The cement cost $2 a barrel at the railroad station, two miles from the work. The gravel was hauled about ½ mile with teams at 40 cents an hour, each team hauling six or seven 1 cu. yd. loads in 10 hr.

Molding Gang Making Concrete Pipe.

Sections of 30 and 38-Inch Pipe.



Parts of Mold for Concrete Pipe.

Placing Concrete Pipe.—The volume of water in the gravel in which the gathering galleries and the upper end of the concrete pipe section of the flow line were laid, together with the considerable depth of the trenches required for the galleries and for part of the flow line rendered this work very difficult. The trench work and pipe laying were started at the outlet end of the 30-in. waste line extending to the river from the waste-way chamber on the flow line, and were carried forward to that chamber. After the latter was reached, the flow line was built up to the gathering well and then the two galleries were carried ahead from this well. The completed pipe could thus be utilized to handle a part of the tremendous amount of water entering the trench. Starting at the waste-way chamber and continuing for 1,000 ft., however, a 12-in. sub-drain was laid in the bottom of the trench ahead of the 38-in. pipe, and from this point two 12-in. sub-drains were laid to the gathering well. These drains were connected into the main pipe at intervals, and assisted materially in the pipe laying, although two 8-in. centrifugal pumps had to be kept in continuous action while work in the trench was in progress. In order not to conflict with any underground water rights the connections between the sub-drains and the main pipes outside of the property owned by the company have been plugged and this water closed off.

Most of the trenches for the work just mentioned had to be closely sheeted and the sheeting heavily braced. The pipe leading from the waste-way chamber to the river was laid in a shallow trench, or on low embankments and involved no difficulties. The first 1,000 ft. of the flow line upstream from the waste-way chamber was in a trench which gradually increased in depth up to 12 ft. in that distance. This portion of the trench was excavated with teams and scrapers and by hand, in the usual manner, although most of it was sheeted before the pipe was laid. The remaining mile of the upper end of the flow line, the gathering well and the galleries had to be built in trenches varying from 12 to 26 ft. in depth; in fact, the average depth of the trench for the main gallery was about 22 ft. The trenches for the 38-in. pipe had to be made 8 ft wide, and those for the 30-in. pipe, 7 ft. wide, in order to provide space inside the sheeting to lay the pipe; in the gallery work water was also encountered 3 to 4 ft. below the surface, so the placing of these pipes involved much difficult work.

Trenching Machine with Gravel Screens.

A Potter sewer trenching machine was installed after the depth of the trenches reached 12 ft. and was used throughout the remainder of the work with a great deal of satisfaction. The trenches were sheeted with 2 x 8-in. planks in 12, 14 and 16-ft. lengths, depending on the depth of the trench. Against the sheeting were placed 6 x 6-in. rangers, which were braced apart with 2-in. Dun extension screws on 6 x 6-in. drums. At first, 1½-in. screws were used for this purpose, but as the depth of the trench increased these were crushed by the side pressures on the sheeting.

The pipes were all rolled from the storage piles near the warehouse to the position they were to occupy in the trench. Each section of 38-in. pipe weighed about 940 lb., and each section of 30-in. pipe, about 500 lb. On ordinary ground one man could readily roll a section of either size. Some of the pipe, however, were transported about 2½ miles and had to be taken up a considerable grade in going from the first to the second bottom of the river. As rolling pipe up this grade by hand was very laborious, a wooden frame, similar to a wire reel, was made to fit inside the pipe and a hose attached to a gas-pipe axle in this frame. A very small percentage of the pipe were broken in transit, either when rolled by hand, or drawn by a horse. A portable, four-post windlass frame, set on the top braces of the sheeting, was used to great advantage in lowering the sections into the trench.

The trenches were back-filled by the Potter machine as rapidly as the pipes were laid. In order to protect the open joints as much as possible from silting, and to increase a free circulation of water around the pipes, coarse gravel was used in backfilling up to 2 ft. above the top of the pipe. This coarse gravel filling was obtained very economically by swinging a series of inclined screens from the frame of the trenching machine, these screens being directly under the dumping platform. The screens were graded from small mesh at the top to coarse mesh at the bottom, so the coarsest material from the excavation was delivered around the pipe.

While the coarse gravel covering unquestionably increases the efficiency of the galleries, the amount of infiltration area provided by the open joints in the galleries is greatly in excess of the cross-sectional area of the pipe, as may be seen from the following: Assume the joints, which are intended to be ⅜ to ½ in. wide, to have an average width of only ¼ in. Then forty joints of this minimum width will have an area equal to that of the cross-section of the 38-in. pipe. Since there are about 1,600 joints in the main pipe and 700 in the latteral, the amount of extra infiltration area will safely permit much closure of the joints by settlement of by silting. As the pipe are laid on firm gravel, little settlement will probably occur, and the gravel being free from much fine material, no appreciable silting is expected. Notwithstanding these favorable conditions, a crib was built around the last 200 ft. of the main gallery to determine the effects of such construction. The lower row of sheeting on both sides of the trench in this distance was left in place, and a flat top of 4-in. plank was laid between the sheeting, over and 3 ft. above the pipe. The quantity of flow through the gallery, which had been previously recorded as the construction advanced, was greatly increased in proportion by the addition of the 200 ft. of gallery protected by the crib, due, it is considered, to the increased freedom with which the water circulates around the pipe in the crib. Based on this result, 1,000 ft. of the 1,400 ft. lateral gallery was built entirely in the crib and has proved very efficient.

Flow Line.—The 10-mile flow line from the gathering well to the distributing reservoirs near the city has a hydraulic grade line of 8 ft. to the mile and a carrying capacity of 30.454 cu. ft. per second, or about 19,000,000 gal. per 24 hours. As has been stated, the first 10,350 ft. of this line is of hub and spigot concrete pipe. The balance of the line is of spirally-riveted steel pipe, built by the American Spiral Pipe Works. The first 19,920 ft. of this pipe following the concrete pipe is 38 in. in diameter; the next 19,082 ft. is 36 in. in diameter and the remainder is 34 in. in diameter. All of this steel pipe has lap joints, with patented fastenings between the sections.

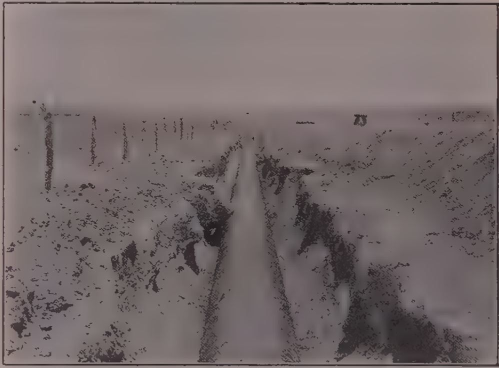
Automatic air valves are placed on all the summits in the line, and blow-off valves at all of the low points. A gate for removing sand from the line is placed in a concrete chamber built around the pipe about 3 miles from the gathering well, this gate being the first opening in the steel-pipe section of the line. All the various air and blow-off valves are also placed in concrete chambers, with heavy cast iron covers. The blow-offs are arranged to deliver water at a position at the side of the line which will avoid danger of washing the latter.

The provision to prevent washing is specially necessary, due to the nature of the soil in which much of the pipe is laid. Bed rock in the country traversed by the line is at various depths, but is at no place far from the surface; over the rock is generally an adobe soil which washes badly, cuts made in it by water continuing down to shale, or to the bed rock. At several arroyos, or water courses which are generally dry, that are crossed by the line ample means of protecting the pipe had to be provided, since occasional severe storms in the district offer a serious menace. These arroyos generally have steep banks, so the pipe was laid in their bottoms and well surrounded by concrete. In some cases, masonry abutments were also built well back in the banks at the end of this concrete protection.

The pipe-laying work on the flow line involved comparatively few difficulties. The trench for this line and the one for the line leading from the reservoirs to the city were made with a Chicago sewer trench excavator. The trench was made 5 ft. wide and an average of about 5½ ft. deep. The machine worked to peculiar advantage in the dry adobe soil and shale that was encountered, the trench all being made without sheeting. The trench excavation cost close to 25 cents a cubic yard. A slightly lower contract price than this might have been obtained, if the work had been done by teams, but the extra excavation thus involved over that removed by the machine would have nearly balanced the cost. The straight, accurate trench made by the machine also simplified pipe laying and back-filling.

The joints in the concrete pipe section of the flow line were made as the pipe was laid, and were afterwards carefully pointed and smoothed by a man working on the inside of the pipe. A small four-wheel truck, with axles of gas pipe bent as arcs of a circle, so the wheels could run normal to the inside of the pipe, was used to great advantage in moving along in the pipe and in delivering mortar to the masons. A platform on the truck was set low enough between the curved axles so a man could bear on it with one knee and push the truck ahead with the other foot. The debris which had collected in the pipes during construction was also removed as the joints were pointed, and was hauled out in the truck.

Distributing Reservoirs.—The two distributing reservoirs on the hill near the city are built partly in excavation and partly in embankment, the excavation being about sufficient to form the embankments. The reservoirs are both rectangular and are built together, with an embankment separating them. Each reservoir is 234.5 x 474 ft. in plan, the combined capacity of the two being 25,000,000 gal. The dividing embankment is 20 ft. wide on top and has 1½ to 1 slopes. The outside embankments are 25 ft. wide on top and have 1½ to 1 slopes on the reservoir side, and 2 to 1 slopes on the outside. The embankments were made with the material from the excavation, which was mostly handled into place with scrapers. The material is a plastic clay that makes practically water-tight embankments. The inner slopes of all embankments and the bottoms of the reservoirs are lined with concrete, however, to prevent washing and to reduce seepage.



Section of Pipe before Being Covered.

Typical Arroyo Crossed by Flow Line.

The slope lining is 6 in. thick at the base and grades down to 4 in. in thickness at the top. Along the lower edge it rests against a continuous block of concrete, 2 x 4 ft. in cross section, and is continued back horizontally on the embankment for 3 ft. at the top, when it is tied to a curb 12 in. wide and 18 in. deep. The lining is reinforced with continuous strips of expanded metal, and at the bottom is tied to the base block by corrugated bars. Transverse joints, extending from the top of the slope to the bottom of the reservoir are placed 12 ft. apart in the slope lining.

The bottom is lined with a 6-in. layer of concrete, without reinforcement. This lining is laid in 12 x 12-ft. blocks, with the joints between the blocks filled with asphalt. It is proposed to eventually cover both reservoirs with a tight wooden roof, and to this end concrete piers are placed in the floor lining, 24 ft. on centers in both directions.

The concrete used in all of the lining work was made in the proportions of 1 part Portland cement to 5 parts river gravel, the latter being of the same character as that used in making the concrete pipe. The concrete for the slope lining was made in a small portable continuous mixer, operating on top of the embankment. This mixer delivered into chutes leading to the point where work was in progress, and was moved ahead as the work advanced, the materials being delivered on the embankment where they could be supplied to it readily. A Smith mixer set up on the embankment produced the concrete used in lining the bottom. This mixer delivered into a feeding hopper, from which the concrete was hauled to place in two-wheel horse carts.

Piping Connections to Reservoirs.—The 34-in. steel pipe of the flow line terminates on the center line of the embankment between the two reservoirs in a 38-in. reinforced concrete pipe, which extends through the outside embankment to a receiving chamber, 4 x 20 ft. in plan and 9 ft. deep. This chamber is at the upper end of the embankment between the two reservoirs and has an opening into both of the latter. These openings are both controlled by sluice gates, so the supply may be cut off from either reservoir. The receiving chamber is also connected with a 30-in. by-pass, laid longitudinally under the embankment between the reservoirs, and discharging at the lower end into the pipe line leading to the city. This by-pass is built of 30-in. concrete pipe protected by 6 in. of concrete reinforced with expanded metal. The by-pass connection in the receiving chamber is likewise controlled by a sluice gate. An overflow weir, with a 6-ft. crest placed 4 ft. below the top of the embankment, is provided in the receiving chamber to limit the height of water in the reservoir. The discharge over this weir passes through an 18-in. tile waste pipe, laid parallel to the 30-in. by-pass and extending some distance below the reservoirs to an outlet in a water course. This pipe is protected under the embankment with a 4-in. layer of concrete reinforced with expanded metal.

The outlet from each reservoir is at the inner downstream corner, where a 30-in. pipe of the same construction as the by-pass is laid under the embankment between the reservoirs to connect with the pipe line leading to the city. These connections are made in a concrete gate chamber built in the embankment, and are each provided in this chamber with a valve. A recording Premier meter is placed on the pipe line just outside the reservoir embankment. Both reservoirs also have a connection to the waste pipe adjacent to their outlet connections. These waste-pipe connections are each provided with a valve, which is placed in a chamber adjoining the outlet gate chamber.

The 2-mile line of 28-in. spirally-riveted steel pipe extending from the reservoirs to the connection with the distribution mains at the edge of the city, is provided with air valves and blow-offs as required. It was laid in about the same manner as already described for the flow line and involves no special features. The connection between it and the distribution system of the north-side water works is made to a main which was laid some time ago to deliver water to a steel tank adjacent to the connection. This tank was provided in order that the higher districts of the north side might be supplied during excessive demands on the pumps of the old system, the latter being operated against direct pressure.

The development of the new water supply which has been described was made by the Pueblo Water & Power Co., of which at present Mr. F. C. Ball is president, and Mr. W. C. Ball, secretary and treasurer. Mr. E. W. Hathaway, as engineer for the company, perfected the scheme of the project, prepared the plans and supervised the construction work, all of which, except a few minor contracts, was done by day labor.

A Break in a Water Main at Derry, N. H., last November, resulted in the sudden loss of the pressure, about 90 lbs. per square inch, and was found only after trying the lines with a pressure gauge in sections and pumping against the gates. The leak was finally located in the main line to the standpipe, and resulted from a crack 6 ft. long in a 10-in. cast-iron pipe.

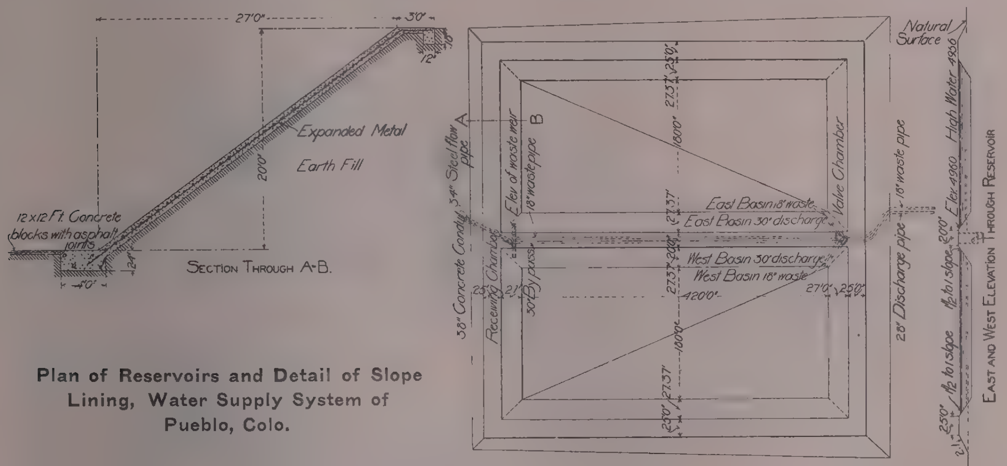
A Commercial Stone-Crushing Plant at North Le Roy, N. Y.

By John Rice, Vice-President of The General Crushed Stone Co., Inc.

The General Crushed Stone Co., of So. Bethlehem, Pa., produced in western New York and eastern Pennsylvania during the operating months of 1907, about 1,200,000 tons of crushed stone, used almost exclusively for railroad ballast, concrete and macadam road construction. The company is at present operating six plants, the largest and best equipped being that at North Le Roy, a description of which is given herein.

This plant, in connection with two others, owned by the company, which are located on the Lehigh Valley R.R., was built for the purpose of ballasting this railroad from Newark, N. J., to Buffalo, N. Y., and, like most other industries of this nature, has been a gradual evolution from smaller things, the present plant being practically the third erected on the same site during the past seven years, owing to the increased demand due to the growth of the good roads movement, and also in the interest of further economies in operation.

The average production is about 50,000 tons monthly of 2½-in. stone, including the smaller sizes. The character of the stone is a hard, tough, gray, limestone in most part, although a considerable portion of the top layers is a flint and limestone conglomerate.



Plan of Reservoirs and Detail of Slope Lining, Water Supply System of Pueblo, Colo.

The general topography being comparatively flat in this vicinity, the quarry was of necessity opened below the general level of the country, and is now down to a depth of about 60 ft. and has a workable face of about 1,800 ft. It is more or less circular in shape and now covers about 15 to 18 acres. The stripping is comparatively light, amounting to little more than a foot. The stone lies in practically horizontal laminations, making it convenient to work the face in four benches.

The drilling is done with F-9 Ingersoll-Rand drills operated by compressed air, drilling holes from 10 to 16 ft. deep according to location of the seams, it being found more economical and satisfactory to drill to these depths rather than to the greater depths to which modern practice seems tending. The blasting reduces the stone to comparatively small size and such stone as may be too large for handling is again drilled with plug and baby drills.

The stone is loaded both by hand and steam shovel. The hand work is paid for by the car, the capacity of which is about 2½ tons. These cars are long and very low to avoid the necessity of raising the material any higher than absolutely necessary. The hand work is done at that portion of the quarry nearest the skip hoist and the cars are drawn from the face to the skip pit by mules over a light 3-ft. gauge track.

On the two sides and back of the skip pit are arranged three tipples from which the cars may be dumped simultaneously and while each skip car will hold but two quarry cars, the arrangement of three tipples renders it possible to always have two quarry cars, at least, on the tipples ready to dump on the arrival of the skip car, thus saving delays at this point.

The steam shovel portion of the work is performed by a 100-ton, Marion steam shovel with 4-yd. narrow gauge Oliver side dump cars and two Porter saddle tank dinkies. These cars are hauled to the same skip pit as the hand loaded cars and are backed across the fourth side of the pit on a raised incline track. When dumping, the train is dropped down by gravity, the locomotive cutting loose as soon as the train is placed, and picking up the last train of empties to return to the shovel, while the other locomotive is spotting another train at the latter point.

The skip cars have a capacity of about six tons each and are hauled by cable alternately from the skip pit to the plant, on an incline about 400 ft. long across the railroad tracks to the crusher. In order to avoid any switches in the skip car track, the rails at the bottom of the incline are laid as close together as possible, the tracks gradually diverging until they give ample clearance at the passing point of the cars, and then continuing parallel to the crusher, where the skips dump automatically off the ends of each track. The rails at the bottom are laid so close together that the position of the alternate skip cars is practically the same, causing no inconvenience in dumping into them. The hoisting cables are attached to a single drum, 75-h.-p. hoisting engine, so that one car acts as a counterbalance for the other.

The stone is dumped on two sides of a No. 10 McCully crusher from which it passes directly into a 5 x 12-ft. screen. The material 2½ in. and under passing through the screen, drops immediately into an elevator; the stone over 2½ in. is rejected into a 12 x 72-in. 5-multiple-jaw Morris crusher which stands below, but slightly back of the screen. This product drops directly into the same elevator that receives the material from the screen.

The elevator has a carrying capacity of about 400 tons per hour, stands at 60 deg. and has 90-ft. centers. It is made of buckets 4 ft. wide and 2 ft. long hung on 2-in. axles at the ends of which are 7-in. rollers running on a track supported by a steel frame. It travels at the rate of 75 ft. per minute and delivers the stone to a chute at right angles to it which discharges into another screen 6 ft. in diameter by 12 ft. long. This screen is jacketed so that it can reject stone of a size over either 2½ in. or 1½ in., returning same through a chute to a No. 6 Gates crusher, located at the bottom of the elevator, which discharges its output again into the original elevator, the product continuing round and round until everything is crushed down to either 2½ in. or 1½ in., which may at that time be desired.

The product, either 1½-in. or 2½-in. stone, passing through the second screen, drops into two chutes which divide the product into two separating screens 22 ft. long. These screens are arranged with one inner cylinder 42 in. in diameter with 2-in. holes, then the screen proper 5 ft. in diameter with 1-in. holes and a jacket with 11/16-in. perforation outside of this.

The purpose of arranging these screens with concentric cylinders with the larger holes on the inside, is to secure large screening area in a small space as well as to utilize the principal of the nest of sieves used in laboratory work, where the top sieve is of larger mesh gradually getting smaller toward the bottom. The material passing through the outer jacket, drops into a bin which is tapped by a small bucket elevator and carried to another screen 40 in. in diameter by 12 ft. long, where the fine product is again separated.

The bins have a comparatively small capacity, only holding about two car loads of the different sizes of stone in each compartment, it being believed that the expense of immense storage bins and distributing machinery, large enough to make them worth while, is not warranted where the units of transportation are small, such as railroad cars.

Passing under the bins is a belt conveyor which taps any one of the various sizes of stone, carrying same to a small bin, off to one side, under which may be driven either a wagon or dump car for the purpose of wasting or storing any size of stone which may not be absorbed by the market that day existing. Material can be stored in this way at a very slight expense, besides permitting a storage to any amount desired. This material can be rehandled in various ways at a small cost and up to the present, comparatively little stone is stored.

Two miles of sidings arranged in three track system above and below the bins with gravity control of cars, gives ample storage and simplifies the handling very much, rendering unnecessary the use of locomotives in the yard. Track scales are installed at the lower end of the yard. A switch of about three-quarters of a mile, affords a connection to the Buffalo, Rochester & Pittsburg Ry., over which the Erie, Delaware, Lackawanna & Western and New York Central can be reached at a moderate switching charge, affording a wide distribution so necessary for the disposition of a large tonnage.

The power plant consists of a 350-hp. Bates Corliss engine, to which is connected a jack shaft by a clutch coupling, from which shaft all the machinery, except the No. 10 crusher, is driven with belts and rope drive. The clutch can be operated from the crusher platform thus enabling the plant to be cut out instantly. From the fly wheel of the engine is driven the No. 10 crusher through a friction clutch pulley on the crusher counter shaft so that this crusher can also be cut out. The fly wheel, belt and crusher pulley is inside and the pulleys on the jack shaft are all outside the engine room so that no belts working in the dust run into the engine room.

A compressed air cylinder is arranged in tandem with the steam cylinder of the engine, furnishing about 800 cu. ft. of free air per minute. This compressor is so arranged that it can be cut out thus enabling the plant to run without compressing air or the plant can be out, enabling the engine to drive the compressor.

The original water supply was pumped from artesian wells but this was so extremely hard that it was found well nigh impossible to maintain the boilers, notwithstanding the use of many different kinds of purifiers and boiler compounds. The only other available supply of good water was the storage of winter snow and spring rain, so one of the quarries, which had been worked to the extent of about 700 ft. in diameter, was turned into a storage reservoir. As this supply was limited and might evaporate or seep away, a 600,000-gal. cooling reservoir was built and a jet condenser installed and the water used over and over again. As this stored water is being constantly distilled, a small percentage of artesian water can be added without any bad results. Moreover, these reservoirs provide a place to pump the water which accumulates in the quarry now in use.

The adding of the compressor to the Corliss engine and the installation of the condenser, effected a saving in fuel and boiler repairs sufficient to cover the entire expense of these additions, including the reservoir, in one season's operation covering eight months.

The exhaust steam from the hoisting engines and pumps passes into a 500-h.-p. Cookson heater which is sufficient to supply the boilers with water at 190 deg. Fahr. A small locomotive air-brake pump, automatically controlled, furnishes blast for the blacksmith shops, the compressed air entering the forges through a funnel on the injector principle, carrying sufficient free air to reduce the pressure and carry a large supply of oxygen to the fire.

The engine house is frame, covered with sheet iron and lined inside with matched flooring. The floor is made of concrete.

The steam plant consists of three 150-h.-p. return tubular boilers. A locomotive air brake pump is attached to the steam shovel which supplies air for emergency plug drill use immediately around the shovel.

The plant proper is not enclosed or housed in for three reasons: expense, greater fire risk and the confinement of dust, which had better blow away. No deterioration to this class of machinery occurs from exposure to weather and the value of the opportunity of making repairs in inclement weather, is not deemed sufficient to offset these objections.

The reason for loading cars both by hand and steam shovel is that the desired output is too large for one shovel and not large enough for two. Moreover, when it is considered that a high-grade shovel plant with the incidental features costs from $30,000 to $40,000, it is at least debatable whether the advantages are not rather imaginary than real.

One hundred Rodger ballast cars are owned by this company which are used for the distribution of ballast. Over 2,500,000 tons have been shipped from this plant in the last seven years, practically during the period from April 15 to Nov. 1.

Paris Underground Railways now open for traffic have a length of 32 miles, out of a total authorized of 57 miles, work being in progress on all lines which are not yet in operation. The Metropolitan scheme includes two tracks parallel to the Seine and serving the traffic of the central portions of the city, a circular line surrounding the city and situated between the central quarters and the fortifications, occupying somewhat the position of the outer boulevards, and lastly, two transverse lines at right angles to the course of the river. The portions of this system now in operation carry an average of 350,000 pasengers daily. The other concession, called the North and South railway, crosses Paris transversely from north to south and has a total length of about seven miles, all of which is now under construction. The system has a double-track tunnel throughout, except where it crosses under the Seine, through two iron-lined tubes, each 16.4 ft. in inside diameter. These subaqueous tunnels are being excavated under pressure by the shield method. The cast iron rings are 23.4 in. wide and 1 in. thick, each ring being composed of 12 flanged segments bolted together.

Erecting the Springfield Bridge on Semi-Suspended Falsework.

Bridge No. 111 of the Boston & Albany R. R. crosses the Connecticut River between Springfield and West Springfield, Mass., with seven 176-ft. spans. The two-track structure erected in 1873 had three lines of riveted Warren girder triple intersection trusses 24 ft. 3 in. deep over all and 14 ft. apart in the clear with 11-ft. 9¾-in. floor panels. The trusses were very light with T-shaped top chords and double-web trough-shape bottom chords connected with diagonal members inclined about 45 deg. from the horizontal. At the center of the trusses these members were made with single pairs of 3 x 3 and 3½ x 3½-in. angles and at the ends with double pairs of similar angles reinforced in a few cases by flange cover plates. At intersections the diagonals were riveted to small connection plates and the end connections were in many cases made with only a few rivets in the webs of the top and bottom chords and in other cases had very small connection plates to the chord webs. The floor was made with plate girders 16½ in. deep and two lines of 10-in. I-beams under each rail. The top and bottom lateral systems were made with zig-zag and X-brace systems of small single angles.

New Connecticut River Bridge at Springfield, Mass.

In 1888 the bridge, under the direction of Mr. W. H. Russell, chief engineer; Mr. Walter Shepard, assistant engineer, and Mr. W. G. S. Chamberlain, bridge engineer, was reinforced while in service to carry a consolidated locomotive with four axle loads of 26,250 lb. each, spaced 5½ ft. apart. Cover plates were added to the chords and diagonal members of the main trusses without interrupting traffic and the sections were thus increased to reduce the working stress in the top chord to between 7,000 and 8,000 lb. per square inch and correspondingly in other members. A new floor and new lateral systems were provided, the former having plate girder beams 26 in. deep with drop ends seated across the lower chords. Two lines of the old 10-in. I-beams were moved out near the ends of the floor beams and three new lines of 15-in. I-beam stringers weighing 200 lb. per yard were placed under each track.

During the season of 1905 the old superstructure was replaced by new steel Pratt truss riveted spans designed in accordance with standard practice to carry the present traffic and provide for future increase. The new trusses are 30 ft. deep and 16 ft. 9 in. apart on centers, with inclined end posts and subverticals dividing the lower chord into twelve 14 ft. 8 in. floor panels.

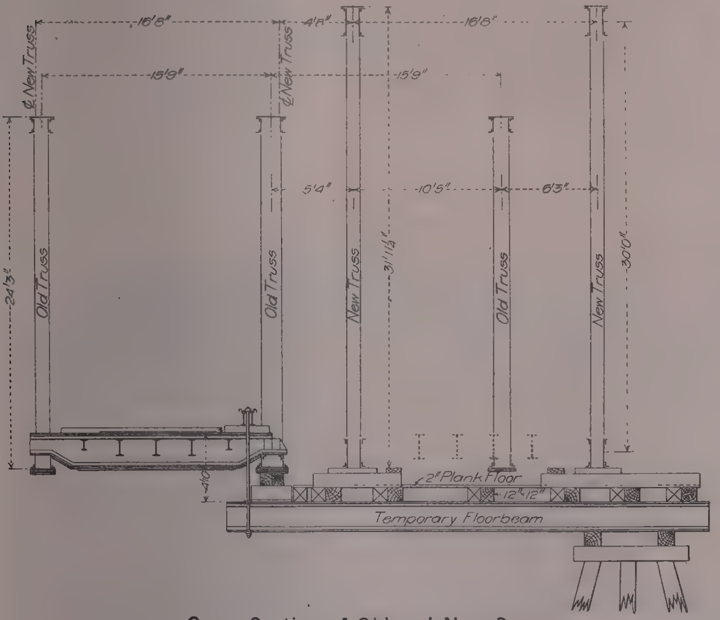
As the old sub-structure was in good condition it was retained to support the new superstructure and it was required that traffic should be maintained while the latter was being erected. The old three-truss double-track spans have been replaced by 14 single-track spans of the same length in two parallel lines 21 ft. 4 in. apart on centers. This arrangement shifted the axis of the bridge 3 ft. transversely and enabled the new trusses to be erected clear of the old ones.

The north trusses of the old spans were supported on falsework; traffic was diverted to the south track, carried by the old center and south trusses; the old north trusses and floor removed and all of the north spans of the new structure were erected on the falsework, making a complete 7-span single track bridge, to which train service was transferred. The falsework was shifted to support the old center and south trusses and they were removed and the south spans of the new structure were erected, and finally trains were admitted to the south spans of the completed new structure.

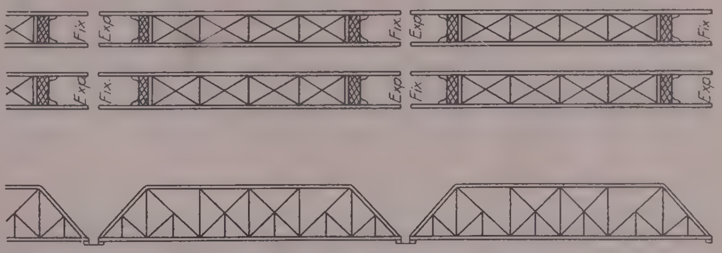
In order to reduce the cost and time of erection, facilitate the support of both old and new trusses, and diminish as much as possible the number of piles driven in the river, the steel work was supported on special falsework made with iron floor beams in each panel which at one end were suspended from the existing steel superstructure and at the other end were supported on single pile trestle bents. The platform was first built on the north side of the axis of the old bridge and supported the new north spans and the north side of the old spans, after which it was removed to the south side of the axis and similarly supported the new south spans and the remainder of the old spans. By this arrangement three 180-ft. sets of single track falsework moved successively from span to span and from up to down-stream sides of the bridge served, economically, for the erection of the 14 spans of new superstructure and the removal of the 7 spans of old superstructure. While the first span was being removed the steel for the second was being put in place and the third span riveted up. The principal features of one span of falsework and its relation to the old and new superstructure, as first placed for the erection of one of the north new spans, are indicated in the accompanying plan and cross section.

Transverse pile bents were driven clear of the old trusses on the north side of the bridge at the panel points of the new superstructure, which in most cases were not coincident with the panel points of the old superstructure. The bents were capped and were connected by two lines of longitudinal walling pieces and were surmounted by single story framed bents about 16 ft. high carrying two lines of 12 x 12-in. longitudinal stringers. Twenty-six iron floor beams about 33 ft. long were brought out on the north track of the bridge, lowered through its floor, swung transverse to the axis and supported at one end on the falsework stringers over the trestle bents and at the other end suspended from a pair of longitudinal I-beams seated on the old south track floor beams just south of the middle truss.

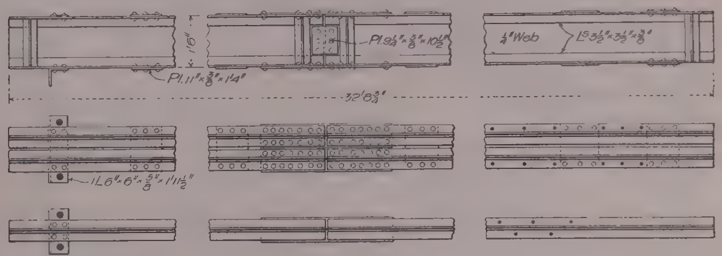
Traffic was diverted from the north track, part of the old floor was removed and six lines of 12 x 12-in. longitudinal stringers were laid on the falsework floor beams, the space between these beams and the old center truss lower chord being filled with blocking that was wedged tightly to hold the falsework platform in place. A 2-in. plank floor was laid on the falsework stringers, the north truss was blocked up from it and removed.



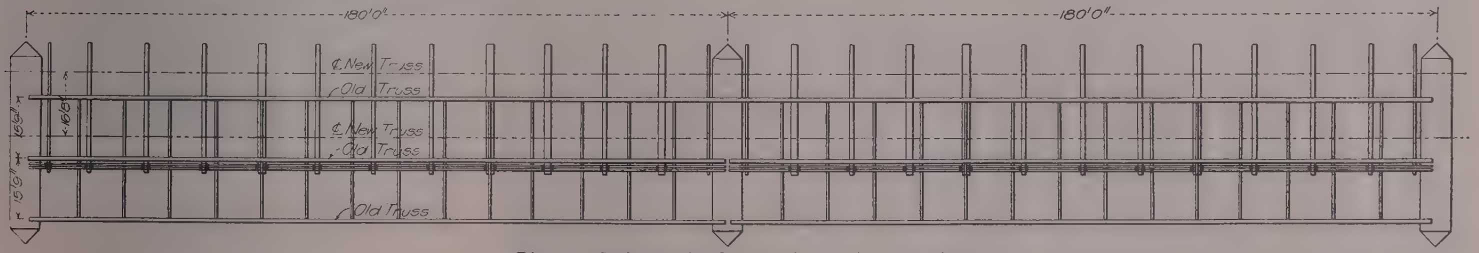
Cross Section of Old and New Spans.



New Spans of Connecticut River Bridge.



Details of Floor Beams.



Plan of Falsework, Connecticut River Bridge.

Cambre blocks were placed for the new single track span and this was erected in the ordinary manner by two derrick cars working from both ends toward the center of the truss. The gantry traveler indicated in the cross section was not used, although it was contemplated in the preliminary design. Material was delivered by the derrick cars from the west end of the bridge, the old material being taken out at the east end. The two derrick cars used were placed facing each other, the easterly one being mostly employed in taking down the old spans. The heaviest members handled were the 10½-ton middle sections of the lower chord which were well within the derrick car capacities. The single track spans were erected at an average speed of about six days each, counting the time after the old steel work was removed and exclusive of the time required for field riveting. These latter operations and the placing of the falsework were carried on simultaneously with the placing of the new spans, enabling the work to be prosecuted continuously at this rate.

As soon as each successive span was erected and swung clear of its falsework the latter was removed, carried forward two spans and put in position for the second span ahead. During the erection of the last north new span, the falsework for the preceding north span was removed and was set up at one end of the bridge on the south side, the piles were again driven clear of the outside of the outer truss of the old superstructure and supporting one end of the floor beams, which in this case had their opposite ends suspended from the floor beams of the new span, thus making them entirely independent of the old structure.

As soon as the new north spans were completed, traffic was diverted to them, and the south track of the old structure being thus released the center and south trusses and remainder of the steel work for the first span were entirely removed from the falsework, leaving the latter unobstructed for the erection of the first new south single-track span which was erected in ordinary manner, after which the work proceeded in this way until the remainder of the old structure was removed and all of the south spans of the new structures were in position. Except as already described the erection was carried on in the usual manner and the old structure weighing about 2,000 tons was removed and the new structure weighing about 3,000 tons was completed in about 100 days by an average force of 40 men. Field rivets were driven by 5 pneumatic hammers and the steel was handled by the standard 25-ton derrick cars built by and belonging to the bridge company.

A considerable economy in the falsework was effected by the utilization of second-hand bridge stringers and floor beams for the suspended transverse girders. Adjacent to the piers where the girders carried only half loads were single-web plate girders 18 in. deep and 32 ft. 8¾ in. long made from a pair of old track stringers spliced together at the center with shop riveted flange and web splice plates. At one end a 6 x 6 x ⅝-in. transverse angle was riveted across the bottom flange to form a bearing bored to receive the lower end of a pair of 1⅞-in. vertical screw rods by which it was suspended from the floor beams of the old south track or of the new north spans. Part of the intermediate falsework girders were 24 in. deep and 33 ft. long, each made with one 22-ft. old floor beam and half of another old floor beam spliced together with shop-riveted web and flange splice plates. The flange splice was made with two 9½-in. plates, one of them, the first, about 5½ ft. and the second about 2½ ft. long. The remainder of the girders had a box-shape cross section and were each made with four old stringers like those used for the pier girders. The stringers were placed side by side 8½ in. apart on centers and their top and bottom flanges were connected by bolted tie plates 11 in. wide. The vertical suspender rods for the inner ends of the girders took bearing at their upper ends on continuous pairs of 12-in. I-beams made from 60-ft. lengths connected with bolted web splices. Bearing plates ¾ in. thick were placed across the tops of the beams in order to receive the vertical rods.

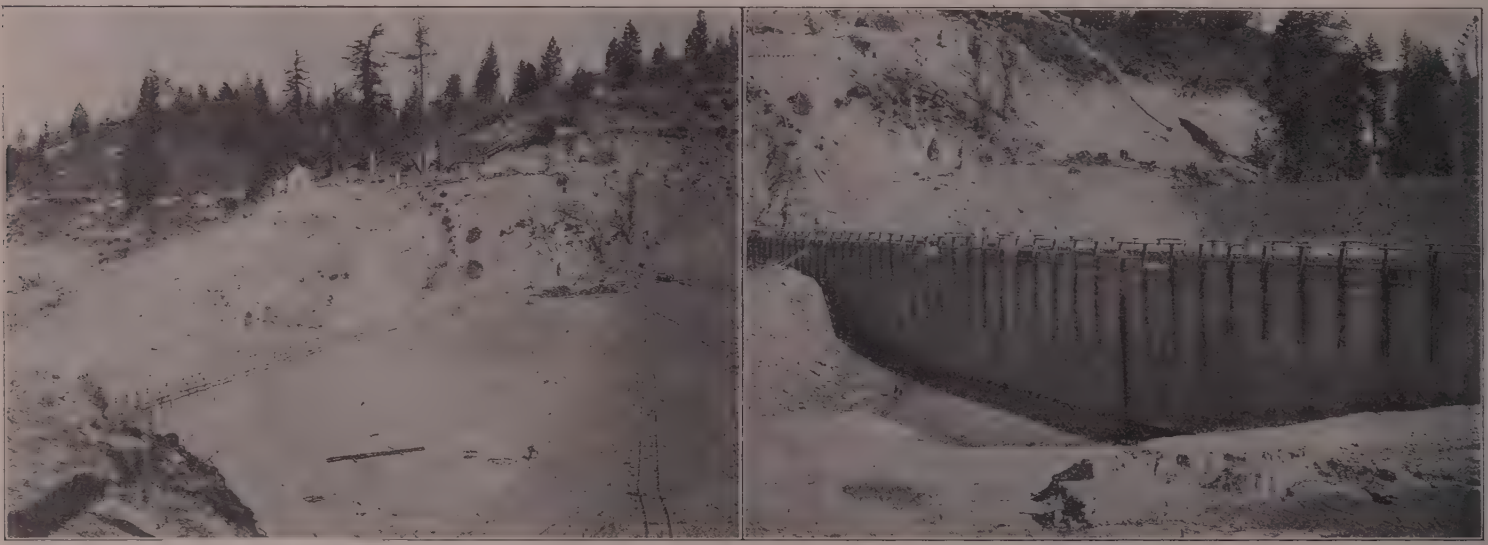
The work was done under the direction of the Engineering Department of the Boston & Albany Railroad, Mr. Walter Shepard, chief engineer, and Mr. W. G. S. Chamberlain, bridge engineer. The new spans were fabricated and erected and the old spans removed by the Boston Bridge Works, Mr. D. H. Andrews, president, and Mr. M. F. Brown, chief engineer, and Mr. J. C. Moses, engineer of construction.

The Testing Laboratory under the direction of Mr. Edwin A. Fisher, city engineer of Rochester, N. Y., is a large branch of his office, occupying five rooms in the Municipal Building and a section of the basement. It contains apparatus for testing cement and concrete, asphalt, paving brick, and the candle power of gas.

A LARGE IRRIGATION AND POWER PROJECT IN SOUTHERN CALIFORNIA.

The Arrowhead Reservoir & Power Co., of San Bernardino, Cal., has under construction in the San Bernardino Mountains a very comprehensive irrigation and power project. These mountains are in a continuous range, which extends almost straight east from the coast in the southern part of California. On the south side of this range is a region of remarkable fertility, much of which is given over to intense cultivation under irrigation. To the north of the San Bernardino Mountains is the Mojave Desert, a part of the vast waste area that extends for hundreds of miles to the north and east. The mountains form the watershed between the fertile cultivated region on the south and the desert on north, the streams which head on their south slopes extending to the Pacific Ocean, some 75 miles distant, while those from the north slope are dissipated in the sands of the desert.

The waters of the streams from the south slope, up to and including a considerable flood flow, have for years been appropriated for irrigation and domestic purposes. The tremendous productivity of the rich soil on the south side of the mountains under the remarkable climate of Southern California has given a great commercial value to the rights under which these waters are diverted for irrigation. At the same time comparatively few attempts have been made to utilize the waters of the streams from the north slope of the mountains for irrigation in the desert, except on the land bordering the streams. The failure to use these waters has been due chiefly to the inadaptibility of the soil to the construction of irrigation works and the economical distribution of water.



Close Views of Dam Embankment under Construction, Showing Method of Placing Materials.

The project of the Arrowhead Reservoir & Power Co. contemplates the impounding of such portion of the flood waters of the Mojave River, one of the principal streams that head on the northern slope, as it is possible to gather in the upper tributaries and the conducting of these waters through the mountains to the rich valley on the south side of the latter. The catchment area of this river above the Victor Narrows in the desert, at which point its surface flood flow is probably greatest, is 352 square miles, of which 72 square miles are included in the Arrowhead project.

The project was first contemplated in 1892 to provide water solely for irrigation purposes. After a considerable volume of construction had been done at that time the management decided with far-sighted conservatism that the knowledge of the extent of the dependable water supply available was insufficient, and accordingly ordered a partial suspension of actual construction, pending the results of a most comprehensive investigation of that leading factor of the project. Under the direction of the late Mr. H. B. Hedges as chief engineer, weirs and rain gauges were established over the proposed catchment areas and the observations made on these were systematically recorded. Meantime, a certain amount of construction work was prosecuted to prove good faith and to preserve rights. Hydrographic observations are still continued, and it is doubtful if more complete information on which to base an estimate of cost and output have ever been available in connection with any similar project in California, or even in the entire West.

The rainfall and run-off conditions in the region in which the project is located are peculiar. Practically all of the precipitation occurs between October and May, inclusive, of each year, the remaining months being almost entirely devoid of rainfall. Generally speaking, the principal rains are borne in from the Pacific Ocean by southwest winds. Comparatively little of the moisture carried by these winds is precipitated in the area between the ocean and the south slope of the mountains, although this area contains some fairly high mountains. As the clouds strike the main range, however, they are quickly condensed by the cooler air encountered there, with the result that the rainfall along, and just over the crest of the mountains is heavy. The average annual rainfall in the valley directly to the south is probably about 16 in., although the variation from year to year is extreme. A similar variation occurs in the mountains and strictly local conditions in the latter produce tremendous rainfalls in small areas. For these reasons it is impossible to state an average for the portion of the catchment area of the Mojave River included in the project. A total annual precipitation of 86 in. recorded in one small area is the maximum, although in various canyons included in the available catchment area the rainfall is heavy.

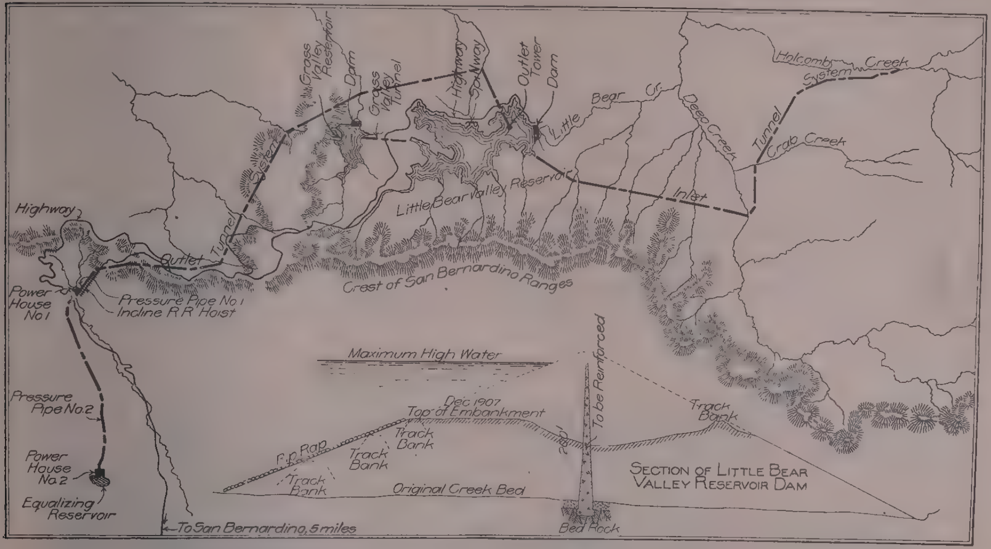
The water-shed between the streams flowing to the south and those flowing to the north is well toward the south of the main part of the mountains. This condition results in most of the rainfall being tributary to streams which flow into the desert and are lost. On account of existing conditions, however, the diversion of these waters to the southern slope necessarily involves works of large magnitude.

The project contemplates the construction of two reservoirs to the north of the divide to impound the flood-water run-off from the tributaries of the Mojave River lying east of Little Bear Valley, and the diversion of these waters through the mountains to the south slope of the latter. The streams to be utilized are all tributary to Deep Creek, which is the east fork of the river. They include Deep Creek, Holcomb Creek and Crab Creek, which, together with the catchment area of the Little Bear and Grass Valleys, are sufficient under the storage to be provided to maintain a large continuous flow throughout a period of such extreme drought as obtained in this region during 1896-1900, inclusive. This flow, with the head that is obtained in connection with the project, will insure the development of an amount of electrical energy equal to the needs of a large community.

The general location of the reservoirs and of the creeks to be made tributary to them are shown in an accompanying map of the project. The largest reservoir is under construction in the Little Bear Valley. The other is supplementary to this one and is to be built in Grass Valley, which is a short distance to the west. The streams whose flood waters are to be impounded, aside from those in the two valleys containing the reservoirs, all lie to the east of the Little Bear Valley reservoir. A series of tunnels is to be built from an intake on Holcomb Creek, the stream farthest to the east, to this reservoir, with provisions at the crossings of the various other streams to divert the flood flows into them. The tunnels will be 7.2 miles in length and will have a carrying capacity ranging from 200 cu. ft. per second at the upper end to 1,100 cu. ft. per second at the reservoir. The tunnel routes are planned to emerge at or near the surface at such intervals as will keep boring lengths within economical limits. Points of changed direction are generally underground, reached by short openings from the surface, making the series practically continuous.

The Little Bear Valley reservoir is being developed by the construction of a dam across a narrow canyon at one end of the site. This dam is an earth and rock-filled structure, with a concrete core wall carried down to bedrock. It will have a maximum height of 200 ft., will be 20 ft. wide and 880 ft. long on top, with a 2½ to 1 slope on the upper face and 2 to 1 slope lower face. The concrete core wall is 20 ft. thick from its base, the natural surface of the ground, and is then battered on both sides to a thickness of 10 ft. at a height of 63 ft.; at that height the batter changes so as to produce a thickness of 3 ft. at the top of the wall, which is at the high-water line of the reservoir, the top of the embankment being 15 ft. above that line.

This dam develops a reservoir covering an area of 883 acres with a maximum depth of 160 ft. at the outlet. A tunnel, 3,880 ft. long, has been built to deliver the water from the Grass Valley reservoir into the Little Bear Valley reservoir. The outlet from the latter is through a tunnel which connects to an outlet tower in the reservoir, some 2,000 ft. upstream from the dam. A spillway of sufficient capacity to carry any floods that may occur can be provided in a depression along one side of the reservoir nearly a mile above the dam. This depression is at about the same elevation as the high-water level in the reservoir for a width of 150 ft. A natural water course leads away from the spillway in such manner as to be entirely isolated from the dam. The main outlet tunnel also terminates where the flow from it can never reach the dam, and the portal of the Grass Valley tunnel is at the other end of the reservoir. The dam is, therefore, entirely independent of all inlet and outlet connections and is also free from any danger of wash from spillways.



General Plan and Section of Dam, Arrowhead Reservoir & Power Co.

Little Bear Valley Reservoir Dam under Construction.

The waters will be conducted from the outlet tower through an almost continuous tunnel, 9.8 miles in length, that extends through to the south slope of the mountains. At the breaks in this tunnel short lengths of covered concrete conduit and steel siphons are inserted, only 0.35 miles of conduit and 0.26 miles of siphons being required in all. The project was first undertaken in 1892 with the view of delivering water for irrigation purposes only, since at that time the construction of large hydro-electrical developments had not been considered. Owing to this and other conditions various features of the original plans for the outlet system have been materially modified. The outlet system from the reservoir as formerly contemplated was an open ditch with tunnels at various points as required. This ditch was finally superseded, after various other types of conduits following the contours of the hills had been proposed, by the practically continuous tunnel of the present plans. This tunnel enables a considerable saving in distance to be made and permits an increase of about 35 ft. of head to be obtained at the power developments. At the same time the saving in maintenance and the freedom from interruptions of service brought about by the tunnel, in comparison with any system of open conduits, more than justifies the increase in the cost due to the tunnels.

Under the original plans the tunnel leading out of the reservoir was built and two tunnels were driven on the line of the outlet conduit as proposed at that time. The outlet tunnel from the reservoir already completed is 4,971 ft. long and extends through a ridge at one side of the reservoir from a portal at the site of the tower that is now being built to control the outlet. It was built with straight sides and a circular arched roof, the span of the concrete-lined arch being 6 ft. and the extreme height 6.6 ft. The tunnel was built at a 0.2 per cent. grade. According to the original plans the flow through this tunnel was to be controlled from a gate shaft on edge of the reservoir, 1,100 ft. from the submerged portal, screens being provided at the latter to intercept the entrance of debris. This arrangement was modified later by abandoning the gate shaft on shore and substituting for it a tower at the portal of the outlet tunnel, 1,100 ft. off shore.

The outlet tower is being built of reinforced concrete at a point in the reservoir where the high-water line will be 160 ft. above the top of the concrete base which has been provided on solid rock for it. The tower will have an interior diameter of 9 ft. and will rise to a total height of 184 ft. 5 in. above its base. The water level in the reservoir is expected to vary constantly and between wide limits. In order, therefore, that the water may be drawn from it at the most desirable levels, openings into the tower are provided at intervals of 20 ft. in the height of the latter. These openings are each to be controlled by a specially designed balanced valve. operated from a house at the top of the tower. Each opening is also to be protected by a special squirrel-cage screen, built so it can be hoisted to the surface and cleaned readily.

Seven miles from the lower end of the outlet tunnel at a point where a fall of 1,520 ft. is obtained in the outlet system, a hydro-electric station will be installed to utilize the power thus made available. From this station the tunnel is on a much flatter grade than the slope of the country, so another concentrated drop of 1,867 ft. will be available at the end of the outlet system. This fall will be utilized in a second hydro-electric development.

The tunnels, conduits, siphons and pressure lines of the outlet system will be designed to carry 80 cu. ft. per second in order that the power stations may be operated to meet the peak loads that may be expected to result in the region to be supplied with power. To overcome the consequent conflict with the continuous use of water below the stations for irrigation, an equalizing reservoir will be built to regulate the excess quantity of water used for peak loads to a continuous flow for irrigation and domestic purposes.

The demands for water and power in the region which can be supplied by the development has at all times been greater than the supply. These demands are also growing so rapidly that the market is constantly better. The entire region south of the Sierra Madre Mountains supports a very dense population, which is largely engaged in or dependent on the culture of citrus and other tropical and semi-tropical fruits and products. Still a large percentage of highly fertile land remains untilled owing to a lack of the water that is essentially necessary to place this land under irrigation. The water diverted from the barren north slope of the mountains by this project will be discharged from the equalizing reservoir at the end of the outlet system of the latter at an elevation which will enable its ready delivery to the most desirable of the land as yet not under irrigation on the south slope. It is also probable that a domestic demand of sufficient magnitude to absorb the entire volume of water available will occur, but in any case the requirements for irrigation will be entirely unsatisfied after the waters of this project are all used for that purpose.

Although the two principal corporations controlling the distribution of power in the region south of the mountains have been reaching out long distances for more sources of supply and have built extensive works to develop these supplies, they have been unable to meet the demand.

The power to be developed in connection with this project can be delivered to electric railway systems or divided into several units and sold to municipalities within a radius of 25 miles of the lower power station.

Construction.—The site of the reservoir is in the heart of a rough, mountainous country over the summit of the mountains and 24 miles from the nearest railroad station, which is at San Bernardino. The latter is at an elevation of 1,050 ft. above sea level, while the summit which has to be crossed to reach the reservoir site rises 5,000 ft. above the sea, although only 8 miles in a direct line from the town. Furthermore, most of the difference in elevation is introduced in the last two or three miles just before the summit is reached. The transportation of construction materials and supplies is, therefore, one of the most difficult features encountered in making the development.

When the project was first undertaken in 1892 no mountain roads existed which could be utilized for freighting. On this account part of the first work done was to build a wagon road over which reasonably heavy loads could be hauled. This road has remained in public use since then and when the project was revived it was largely improved and extended. The steep ascent to the summit of the mountains is made by a long series of switchbacks, one above the other on the side of the mountain. The maximum grade up to the base of the switchbacks is 10 per cent., while on the latter grades as steep as 13.5 per cent. are required. In order to eliminate the long, arduous climb introduced by the switchbacks an incline cable tramway hoist has been built from the base to the top of the steepest part of the ascent. This incline rises 1,700 ft. in 4,000 ft. and saves approximately 4½ miles of the climb. It is extended straight up the side of one of the steep hills at grades varying from 16 to 78 per cent.

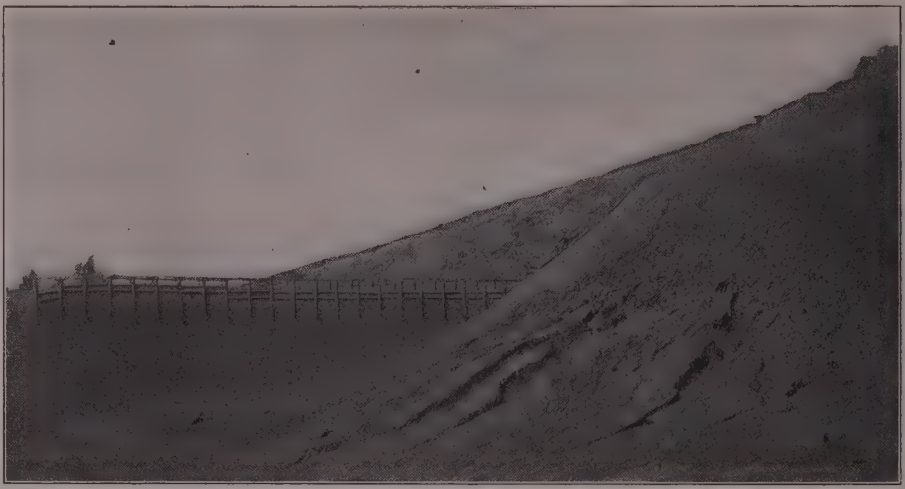
The intention is to equip the incline to handle passengers as well as freight, since pleasure resorts in the mountains are much frequented in the summer. At first it will be operated only for freight, the delivery of which it will greatly expedite. Later, when it is equipped for passenger service, numerous attractive resorts in the mountains now almost inaccessible will be reached easily.

The permanent track has been laid, consisting of three rails spaced according to the standard railroad gauge, with a double-track turn-out midway on the incline. Two cars are to be operated on these rails by means of a 1¼-in. steel cable attached to each car and passing around a Halliday clutch sheave at the top of the incline. This hoisting cable is driven by a 100-h.-p. electric motor hoist. A tail cable, also attached to each car, passes around an 8-ft. sheave wheel on a heavily weighted car at the bottom of the incline. This tail cable provides for the expansion and contraction of the cables and effects a steady movement of the cars. A standing cable, anchored at the top and weighted at the bottom of the incline, passes through automatic clutch devices placed under the cars, affording, it is believed, absolute safety. Owing to the steep and varying grades, the cars and the safety devices have been designed along entirely unique lines. The construction of the track and provisions for handling the cables are also much involved on this account.

From the top of the incline the improved wagon road presents a maximum grade of 6 per cent. against traffic. In most of the remaining 12½ miles to the dam site it is a bench cut up on the sides of the mountains where practically no bridges were required, although rubble masonry retaining walls had to be built in places to carry it along steep side hill slopes.

Since the construction of the dam is the controlling feature of the plans, work has been concentrated on it since the revival of the project. The earth and rock fill of the dam will contain approximately 1,000,000 cu. yd. of material and the core wall 28,000 cu. yd. of concrete. The hills within a reasonable distance of the dam site, and, in fact, practically all of upper strata of the range of mountains in which the reservoir is located are disintegrated granite rock. This material further disintegrates rapidly in the air and is easily blasted from place. It was considered to be impracticable to attempt to convey it into place in the dam by hydraulic methods, however, although its clay content is from 5 to 15 per cent. of the total volume. At the same time, no clay or other suitable material was available where it could be utilized. Consequently, the decision was made to build the heavy concrete core wall and to place the loose, porous disintegrated rock from the adjacent hill sides against it by the following method, which was calculated to produce the best results as to settlement and imperviousness.

In 1904 the core wall was built up to a height of 34 ft. above the solid granite foundation on which it stands, or 12 ft. above the original creek bed. In the following year the embankment of the dam was started with material from adjacent borrow pits. This material was blasted from place and then loaded into 4-yd. dump cars by two steam shovels, the cars being drawn to the embankment in trains by light locomotives. A track bank was first built on the upstream and one on the downstream toe of the embankment, on lines which brought the crests of these banks to the slope lines of the embankment. The outer slope was first completed to that height, and then the material was dumped on the inner or core-wall side of the track banks. A stream from a hydraulic monitor was used under a pressure of 60 lb. to wash the dumped material with much the same results that are obtained by the hydraulic-fill method of dam construction; that is, the water graded the material from the coarsest particles at the top near the slope line to finely divided clay in suspension at the core wall. The top of the track bank was advanced in this manner until only a small basin was left near the wall. Successive track banks were built and the operation repeated in the same way, with the result that a zone of pure clay now lies against both sides of the core wall. The natural porosity of the concrete wall has been effectually sealed by infiltration from the clay puddle.



Effect of Sluicing on Track Bank.

The concrete in the core wall was mixed in a plant erected high up on the hill at one end of the wall. Suitable rock for the concrete was obtained with difficulty, owing to the generally disintegrated nature of the upper strata of the entire surrounding country. A fairly good quality of granite rock was obtained, however, from a ledge in the side of the hill about 1,500 ft. around the point from the mixing plant. This rock was delivered in small cars from the quarry to the plant, where it was dropped by gravity into either or both of two crushers. The product of the latter was raised by bucket elevators and screened into an overhead storage bin.

Sand of proper quality for the concrete was as hard to find in the vicinity as was the rock. A deposit of sand existed in the bed of the stream above the site of the dam, but was filled with small particles of peat brought down from a bog farther upstream by the water. After considerable difficulty had been experienced in an endeavor to clean this peat from the sand, one of the hydraulic monitors was found to be quite effectual for this purpose. Later, when the deposit of sand had been exhausted, a bed of disintegrated granite containing particles of a uniform size was found on the side of the hill above the mixing plant and was utilized in the concrete with screenings from the crushing plant, which furnished about 30 per cent. of the required quantity of sand.

A ¾-in. Ransome mixer was placed under the elevated storage bins for the sand and stone close to the crushers. The concrete was handled from this mixer into place in the core wall by a 980-ft. span Lidgerwood cableway, set up over the axis of the wall. This cableway was also utilized in making the excavation for the core wall.

The upstream face of the dam is being covered with an 18-in. layer of rip-rap, which will be carried to the top as a protection against wave action in the reservoir. The downstream face of the dam will also be protected in some manner against washing due to heavy rains. The rip-rap stone was obtained from a quarry on the opposite side of the canyon from the concrete mixing plant. Those stones were delivered to the top of the embankment and placed by hand, the rip-rap being carried up as the fill progressed.

Operations on the dam were suspended in November last until the weather opens in the spring. At that time the core wall had reached a height of 110 ft. above the foundation and the embankments on both sides of it had been carried up correspondingly. The tunnel from the site of the Grass Valley Reservoir was recently completed and arrangements are being perfected to start the construction of the long outlet tunnel system. No detail plans for the equipment of the power stations have been prepared as yet, although the location and general arrangement of these stations is definitely determined.

Mr. James N. Gamble, of Cincinnati, is president; Victor C. Smith, vice-president and general manager; E. H. Kellogg, chief engineer, and Walter Hy. Brown, assistant engineer of the Arrowhead Reservoir & Power Co. Messrs. F. C. Finkle and F. E. Trask, of Los Angeles, Cal., are consulting engineers for the company.

Laying a 20-Inch Water Main under Sidewalks.

A large water main, comprising 20,526 ft. of 20-in. pipe, was laid during the past summer and fall in Utica, N. Y. The route of the pipe line is in the busiest and most heavily traveled streets of the city and it was important to lay the pipe with as little disturbance to traffic as possible. These streets are for the most part paved with comparatively new sheet asphalt and trenching in the streets would not only greatly obstruct traffic, but would also, on account of the difficulty of satisfactory repairs, shorten the life of a considerable part of the pavement.

A large proportion of the sidewalks along the streets traversed are of the stone flagging variety and it was thought that these could be economically removed and later replaced in a satisfactory manner. These various considerations led to the adoption of a route for the main under the sidewalks wherever possible and in a few places under lawns between sidewalk and curb, thus interfering with neither pavement nor sidewalk. While the advantages of the sidewalk route from an economic point of view were evident there was considerable diversity of opinion among the property owners along the route and the harmonizing of these differences, though finally accomplished, was no small task.

The more prominent direct results accomplished by following out this policy have been the minimum of delay and annoyance to the heavy traffic; the avoidance of a continuous patch along the asphalt pavements which, with the most favorable conditions and the most careful workmanship, must be a serious detriment to the street; the actual improvement of the appearance and quality of the walks by relaying to line and grade and replacing cracked and broken flagging with new stone; and the saving in cost of from $1.50 to $2.00 per running foot, depending largely on the proportion of flagging stone to be replaced.

Owing to lack of accurate records concerning the position of many existing water mains as well as other public service pipes it was impossible to determine in advance of the excavation the best method of making or the exact location of the cross connections between the new and old mains. The ordinary method of procedure was therefore to excavate the trench and lay the new pipe straight through, crossing intersecting streets without regard to the location of the connection, and later make the connections by means of split tapping sleeves. This method allowed the main gang to work uninterruptedly eliminating the delay arising from determining by investigation on the ground, the point at which a tee would have to be set, and the cutting of the 20-in. pipe after such determination had been made. With this delay disposed of, this gang was able, with other conditions normal, to accomplish 300 ft. of completed work per day.

Features outside of the regular street construction were the crossing at two different points under the bed of the Erie Canal, the pipe being encased in a concrete jacket at these points. Pipe weighing 2,250 lb. per 12-ft. length were used for the entire line. All pipes were laid to an established line and grade, the more abrupt changes in direction both horizontal and vertical being made with special bends having a 5-ft. radius, while changes in direction made by deflecting a 12-ft. length of pipe were based on a maximum deflection of 2 deg., 4 min. in a length of pipe from the direction of the pipe next preceding, or laying to a curve with a radius of 233.59 ft.; connections were made with all existing mains at intersecting streets.

The pipe laying gang was followed by a connecting gang which made such additional excavation as was necessary to determine the best method of making each connection and also made the connections. A split sleeve was attached to the new main with the proper size of projecting branch and a similar sleeve with the same size branch was attached to the crossing line. The two sleeves were then tapped out and the branches connected up with suitable lengths of pipe and bends; for cutting the pipe inside the sleeves, a tapping machine made by the Water Works Equipment Co., New York City, was used, with which the work was done without shutting off the flow in the main or reducing the pressure.

The split sleeve for the 20-in. pipe was a modification of those generally employed, being designed for this work, and having a bell and hub branch that the connecting pipe could be leaded directly into, without the intervention of the usual valve. By this arrangement the 20-in. sleeve could be set with its branch at any point on the circumference of the outer shell of the pipe and with the new main passing under or over existing mains. The branch between this sleeve and the regular sleeve and valve attached to the existing main consisted of two short pieces of pipe and a bend, ordinarily a 90-deg., otherwise one of the smaller standard bends, or a combination thereof. This allowed of the shortest possible branch between the mains. The tap in the new main was, of course, made dry. Over thirty connections were made in this manner, mostly with 6 and 8-in. mains. The few connections made with existing 4-in. mains were ordinarily tapped out 8 in. on the new main and reduced temporarily so as to provide for future mains of a larger size without retapping.

The additional labor involved in making the cuts and the additional lead and oakum required for the 20-in. sleeve, over and above what would be required for a regular tee would appear upon first thought to increase the cost over the ordinary method of making connections, but the saving made in 20-in. pipe by avoiding cutting at each of these points and the saving in time by being able to lay the 20-in. line continuously, also in making shut-offs and giving notice of impending shut-offs in many cases to quite extended districts, to say nothing of the advantages of maintaining an uninterrupted service to fire hydrants and consumers, more than offset these items of increased cost.

Between 50 and 60 new fire hydrants with 6-in. and 8-in. branches leading direct from the large main have been installed and are in operation. Each hydrant is supplied with an independent valve so that it can be shut off from the main, necessary repairs made or the hydrant entirely removed and another substituted in its place without putting other hydrants out of commission or shutting off the main line.

On portions of the sidewalk route the distance from the main to curb line was not more than 6 or 8 ft., necessitating very short hydrant branches, the distance between the base of hydrant and branch of a regular tee being altogether too short to attempt of installing a regular 6 or 8-in. double hub valve without danger of its being blown off in case the hydrant were removed for any reason. At such points split-tapping sleeves were again employed, dispensing with regular tees and allowing the valve to be attached directly to the 20-in. main and from thence a short branch leads direct to hydrant. This arrangement precludes the possibility of a blow-off in case a hydrant is removed, giving at the same time a very close connection between hydrant and main. Pressures of from 90 to 108 lb. per square inch are available at the nozzles of the 6-ft. hydrants installed on this line, according to their relative elevations.

The work was done for the Consolidated Water Co., of Utica, partly by the company's own forces and partly under contract, the whole work being carried on under the general direction of the company's chief engineer, Mr. A. B. Tracy.

A Large Double-Barrel Sewer Built across a Salt Marsh.

The Borough of The Bronx, New York City, is cut into two nearly equal parts by the Bronx River, which crosses the borough in a fairly straight line flowing southward. The part of the borough east of the river, which has an area of about 28 square miles, is only partially settled, its general character being in fact rural rather than urban. No sewers have as yet been built in this part of The Bronx except a few temporary sanitary sewers. Within recent years a very definite increase of population has been noted in this territory and eventually it will undoubtedly be thickly settled. Accordingly, a general sewerage scheme has been worked out for the greater part of this section and some of the larger branch sewers are now under construction.

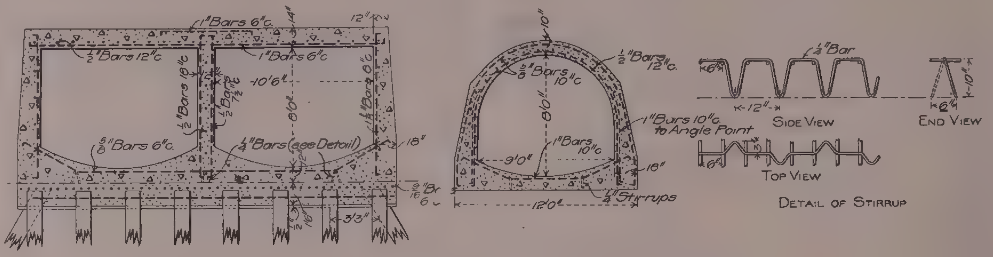
The general scheme involves the construction of a very large trunk outlet sewer in the southern part of the territory, into which several large branches will discharge the house and stormwater flow collected from the various lateral systems. The trunk sewer, as proposed, will have an area equivalent to that of a 24-ft. circular sewer. It will discharge into Long Island Sound, near Clason's Point, east of the mouth of the Bronx River. At present, work is in progress on two of the large branch sewers and their tributary pipe systems, but the construction of the main trunk sewer will be deferred for some time. In the meantime temporary outlets will be provided for the branch sewers so that they may be put in service as soon as completed.

In Avenue E, one of the large branch sewers is now under construction. The part of this sewer now under contract has a total length of 6,460 ft., comprising about 4,000 ft. of double-barrel sewer, each barrel being nearly rectangular in section, 8 ft. high and 8 to 10½ ft. wide; 2,000 ft. of single-barrel sewer, part of which is rectangular, 8 ft. high and 9 to 12 ft. wide, and part arched, as shown in an accompanying illustration; the rest of the sewer is vitrified pipe, 30 in. in diameter and smaller. The sewer is laid practically on tangent throughout its entire length and the gradient of the double-barrel section is .00044.

Practically all of the double-barrel section and a large part of the single-barrel sewer is located in a salt marsh traversed by Pugsley's Creek, where water and unstable soil make construction work very difficult. The general elevation of this marsh is about + 1.5, datum being mean high water level at the Third avenue bridge over the Harlem River. The elevation of the invert varies between about El. — 0.9 and El. + 1.1; the greater part of the sewer is therefore above the general level of the marsh. When the sewer is finished it will be covered with an earth embankment having a minimum depth of 4 ft. over the top of the sewer, and side slopes of 1:1, which will be protected up to El. 6 with riprap. The present outlet of the Avenue E branch will be about 1,000 ft. above the lower end of the work now under contract. Here, Pugsley's Creek flowing between low marshy banks, as shown in an accompanying illustration, approaches within a few feet of the sewer, affording a convenient site for the temporary outlet.

All the sizes of the double-barrel sewer have the same general sectional form as the largest size, which is shown in an accompanying illustration, and in all sizes the radius of curvature of the invert is equal to the width of the barrel. In the largest size the width of each barrel is 10 ft. 6 in. and the height is 8 ft. The outside walls are 12 and 18 in. thick at the top and bottom, respectively, and have vertical inner faces and battered outer faces. Ransome twisted bars are used for reinforcement throughout the work. The outer walls have 1⅛-in. vertical bars 8 in. center to center and ½-in. horizontal bars about 18 in.

on centers. The common wall between the two barrels has a uniform thickness of 12 in. and is reinforced in each face with vertical ½-in. bars 7½ in. on centers; it is also reinforced longitudinally with ½-in. bars placed horizontally, 18 in. on centers, in the vertical center plane of the wall. The top slab is 14 in. thick and is reinforced transversely at intervals of 6 in. with 1-in. bars which extend over both barrels of the sewer. As longitudinal reinforcement, the top slab has ½-in. bars placed 12 in. on centers; there are also continuity bars placed in the top slab over the middle wall, as shown in the illustration. The invert slab has a minimum thickness of 12 in. and is reinforced transversely with 9-16-in. bars 6 in. on centers. These bars are bent to conform in a general way with the curve of the invert. Practically all the reinforcing bars have 3-in. right-angle bends at each end as shown on the drawing. As an additional reinforcement for the invert slabs, there are three lines of zig-zag stirrups, details of which are shown. The concrete used in all sizes of the sewer is a 1:2½:5 mixture of Lehigh Portland cement, Cow Bay sand and crushed trap rock which passes a ¾-in. screen.



Sections of Avenue E Sewer and Details of Stirrups.

View of Avenue E Sewer, Showing Method of Supporting Reinforcement.

Across the marsh the sewer is supported on pile bents placed 4 ft. on centers and capped with an 18-in. slab of 1:2½:5 concrete laid on a floor of 2-in. planks. The spacing of the piles in each bent varies slightly for the different sizes of sewer but in general they are placed about 3 ft. on centers. The piles are driven to practical refusal through the swamp muck and into the hard, gravelly material underlying it. Very short piles are required, the average being about 18 ft., and the limits about 10 and 30 ft. This has occasioned a considerable waste of pile lumber, but it has been possible to use a great many of the sawed-off ends as ties in the various tracks laid by the contractor. During the early part of the work the plank flooring was laid just in advance of the placing of the foundation concrete, being held down by the latter and resting directly on the muck, the plank being laid lengthwise of the trench. Owing to the inequality and softness of the trench bottom this method did not prove entirely satisfactory and now the planks are laid on transverse planks spiked on edge across each bent with their tops 2 in. below the level of the top of the flooring. With this method it is possible to lay the plank flooring considerably in advance of the concrete, the planks being held in place by temporary cleats spiked across each pile bent. Midway between the main bents are bents of battered brace piles, two to the bent, with their heads tied together with ⅝-in. rods. Four inches below its upper surface the foundation slab is reinforced with 9-16-in. longitudinal bars 6 in. on centers.

Concrete Mixing Outfit for Foundation Concrete, Avenue E Sewer.

Practically all the excavation, including that in the swamp, has been handled with a Page scraper bucket excavator, operated by an A-frame derrick mounted with a Lidgerwood engine and boiler on a platform traveler spanning the line of the trench, and carried by four 18-in. double-flange wheels on each side which run on heavy railroad rails. This excavator has proved very satisfactory. The trench through the swamp is sheeted with 2-in. planks, which were easily driven by hand in the soft material. The spoil was delivered along the trench generally on the side nearer the creek to form a barrier against high tides, which sometimes during the season of full moon and with a strong in-shore wind exceeds the level of mean high water 2 or 3 ft. The top 2 ft. or so of the marsh is peaty material, but below this is a bluish muck which, when thrown up in an embankment, becomes practically impervious. This embankment and the trench sheeting have afforded excellent protection against water and the greater part of the pumping equipment brought on the ground by the contractor has not been required. Gates are provided in the sheeting and embankment and when an extremely high tide breaks through it is possible to drain the trench during the next low tide period by opening these gates. As a precaution against erosion where the creek approaches the sewer near the temporary outlet, a double row of piles has been driven for a distance of 200 ft.

The uniform arrangement of the piles in short transverse rows in a long shallow trench suggested a possible economy by designing a traveler upon which to mount the machine or driver for driving them. Accordingly, a traveler specially adapted to this work was built. A heavy timber framework with steel truss rods spans the trench and is provided on each side with two 18-in. double-flange wheels which run on rails about 33 ft. apart. This framework carries two lines of half-round timber skids placed transversely with regard to the line of the trench and about 15 ft. apart. Upon the bed-frame of the driver are bolted semi-cylindrical cast roller chocks, instead of the wooden ones ordinarily used. These chocks fit upon the skids and are spaced upon the driver bed-frame so as to properly balance the leads, hammer, boiler and engine. This scheme admits of the driver being moved readily and quickly to either side of the traveler, by the usual rope tackles, connected to the ends of the skids and to the engine. The traveler is easily moved along the line of the trench by means of a double-block tackle connected to a deadman ahead and to the engine winch. Either a steam driver or an ordinary weight may be used in the leads and both types have been used on the work in question. This driver and traveler has proved very satisfactory for the special work for which it was designed; it is operated by a gang of seven men and has driven as high as 128 of the short piles required in an 8-hr. day.

The foundation slab concrete is mixed in a Smith machine mounted with its engine on a 17 x 33-ft. platform traveler spanning the trench and fitted with double-flange wheels running on heavy rails about 33 ft. apart. The mixer is mounted on the front end of the platform and delivers directly upon the plank flooring over which the concrete is distributed by hand. Behind the mixer over the center of the platform is an elevated charging hopper with its spout placed so that it is over the hopper of the mixer when the latter is tilted back.

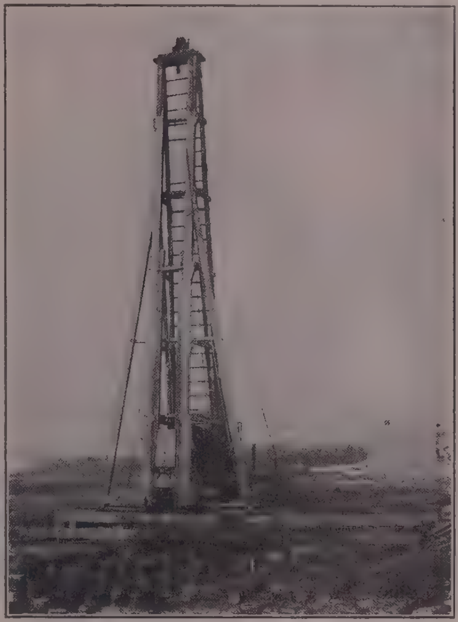
Sand, stone and cement are delivered to the charging hopper in 1-yd. buckets, each bucket containing the proper quantity of the three ingredients to form a batch of concrete. The buckets are handled by an A-frame derrick with a 50-ft. boom, operated by a Lidgerwood hoisting engine and a Dake swinging engine, supplied with steam by a Nagle boiler, which also supplies the engine of the mixer. The derrick engines and boiler are mounted on a 12 x 24-ft. platform traveler running with double-flange wheels on a 10-ft. gauge track. The derrick traveler is placed with its front end about 7 ft. behind the rear end of the mixer traveler and the wheels on the trench side of the former run on the same rails as the outside wheels of the latter. The two travelers are coupled together with a tie and strut so that when the derrick traveler moves the mixer is always in its proper relative position. The two travelers are moved ahead by the derrick engine, which draws on a rope leading from its winch head through a double block attached to sheet piling some distance ahead of the machine and back to an attachment on the mixer platform.

Raw materials are delivered to this section of the work in Western Wheel Scraper side-dump cars handled over 36-in. gauge tracks by a 10-in. Porter locomotive. This track is laid about 20 ft. from the trench, giving room to pile material between it and the derrick track. Sand is piled on the outside of the track and stone on the inside and the buckets are filled by shovelers. The part of the foundation slab below the reinforcing bars is laid first and the rods are then placed and covered with a 4-in. top layer. The general practice is to lay each day as much bottom course as can be covered with rods and top course in the same day.

Near the lower end of the work the contractor has established a temporary dock on Pugsley's Creek, where all materials of construction and equipment are delivered in scows brought up the creek during periods of high tide. On this dock is a guyed derrick with a 50-ft. boom, operated with a Lambert three-drum engine. Sand and stone are unloaded with a 1-yd. Hayward clamshell bucket handled by this derrick and are stored in large piles on the dock. Cement, which is unloaded in stone skips by the same derrick, is stored in sheds nearby.

Along the land side of the dock are two elevated bins, one for sand with a capacity of about 50 cu. yd., and the other for stone with a capacity of 100 cu. yd. The floors of these bins slope sharply landward and each bin has a spout on its side about 15 ft. above the level of the dock floor. Along the side of the bin and about 4 ft. below the spout is an elevated 24-in. track on which a small Koppel turntable measuring car is operated. With this car sand and stone are delivered from the bins to a hopper, with its top at the level of the track, placed over a No. 3 Ransome mixer. A small platform built across the end of the sand bin and contiguous to one edge of the large hopper affords standing room for the cement man.

The mixer delivers to 1-yd. buckets on flat cars, which are handled by the Porter locomotive before mentioned. Two buckets are placed on each car and three cars make a train. The dinkey track is laid parallel to the sewer trench throughout its length. The buckets of concrete are handled from the car to the work by a platform traveling derrick, running on track laid between the trench and the dinkey track, or by guyed derricks erected at convenient points. Steam is supplied to the various derrick, pump and mixer engines near the dock by two 45-h.-p. elevated railway locomotive boilers. Water is piped to all the boilers and mixers on the work from a city hydrant. For removing seepage water from the trench two 8-in. Lawrence centrifugal pumps are provided, but only one is in use.



Special Traveling Pile Driver.

The centers for the sewer were specially designed for this work. They consist essentially of wooden frames supporting planed lagging boards built up in sections of convenient size. The timber frames are collapsible and are designed so as to afford a passageway through the sewer while the centers are in place, thus permitting the dismantled forms to be carried forward as they are removed from the completed part of the sewer through the part in which the centers are still standing. Up to the present time the dismantled forms have been carried through by hand, but it is planned to transfer them on a small flat car running on industrial track laid in the passageway through the centers. The centers are readily adaptable to the various widths of barrel and they effect a very important saving of labor and material over the usual wooden forms. The sewer is constructed in 12-ft. sections and the contractor has provided 150 lin. ft. of centering.

To support the invert and wall reinforcing bars before the invert concrete has been placed, special wooden racks, shown in an accompanying illustration, are used. The invert rods and longitudinal horizontal wall bars are wired to the vertical wall bars and the latter are hung by the right-angle hooks at their upper ends on lines of boards notched to give the proper spacing. These boards are supported at frequent intervals by wooden horses with extension legs made of short pieces of round steel rods clamped to the horse legs with U-bolts. The extension rods are thoroughly greased and the invert concrete is placed about them and allowed to set. The U-bolts are then loosened and the horses lowered so that the supporting boards can be removed, the reinforcing bars being then held in place by the invert concrete and the wiring before mentioned. The steel extension rods being greased, are easily removed from the concrete and the holes are filled with grout.

Manholes occur on the double-barrel sewers at intervals of 140 to 160 ft. They are placed directly over the middle wall, the latter being cut away for a width of about 2 ft. and the manhole steps placed in one of the ends of the wall thus exposed. The weight of each manhole is carried by two transverse 12-in. 40-lb. I-beams imbedded in the concrete of the roof slab and supported at their ends and middle points by 6-in. I-beams placed in the sewer walls.

The embankment over the completed sewer will probably be made of material delivered at the contractor's dock in scows and hauled to place over a dinkey track. It is planned to run this track over the top of the sewer and dump on both sides, the track being laid on an earth cushion, in order to protect the sewer from injury by impact.

General supervision of all work done by the city in The Bronx is exercised by Mr. Josiah A. Briggs, chief engineer of the Borough of The Bronx. The work described is being carried forward under the general direction of Mr. Chas. H. Graham, engineer in charge of sewers; Mr. Josiah H. Fitch, principal assistant engineer. Major Elmore F. Austin, assistant engineer, is directly in charge of the sewerage project for the territory east of the Bronx River, including the work described. The John J. Hart Co. is the contractor for the work, which is being prosecuted under the personal supervision of Mr. John J. Hart. Mr. R. H. Gillespie, consulting engineer to the contractor, designed the collapsible forms, special pile driver, traveler and other details of the contractor's plant. Six hundred days are allowed for the completion of the work; at the end of 130 days about 30 per cent. of the work had been finished.

A Large Grain Elevator at Minneapolis.

A 750,000-bushel elevator has been built at Minneapolis for the Washburn-Crosby Co. to concentrate the car deliveries of wheat for its five mills. The elevator proper covers a space of 79 x 126 ft, and there is an adjoining 42 x 126-ft. unloading shed. The entire elevator is built of reinforced concrete. There are 15 tanks which, with the spaces between their walls, form 29 bins. The tanks rise 92 ft. above the tracks and their hopper bottoms run below the track level, so that the total depth of the tanks is 105 ft. A cupola rises 95 ft. above the tanks and is supported on steel girders and concrete piers carried down 28 ft. below the ground level to bedrock. The walls of the tanks are 11 in. thick at the bottom and 9 in. at the top, and are reinforced by horizontal rods every 10 in. and by vertical rods about 4 ft. apart. Each bin discharges at the bottom on to a 36-in. belt conveyor running in a tunnel about 14 ft. high. The incoming cars are run over concrete pits below the receiving tracks into which the grain is shoveled by machinery. It is then taken by a receiving leg to a hopper scale at the top of the house, whence it falls into a garner and then into a separator, to be cleaned before going to the bins.

THE DEVELOPMENT OF BUILDING FOUNDATIONS.

By Frank W. Skinner. M. Am. Soc. C. E.

A large proportion of the difficult problems in the design and construction of foundations for buildings in this country are encountered in the congested portion of the largest cities where the great heights of the buildings concentrate enormous loads on the columns and in large central power stations where great weight of machinery and equipment are spread over large areas which must be maintained free from danger of vibration or settlement.

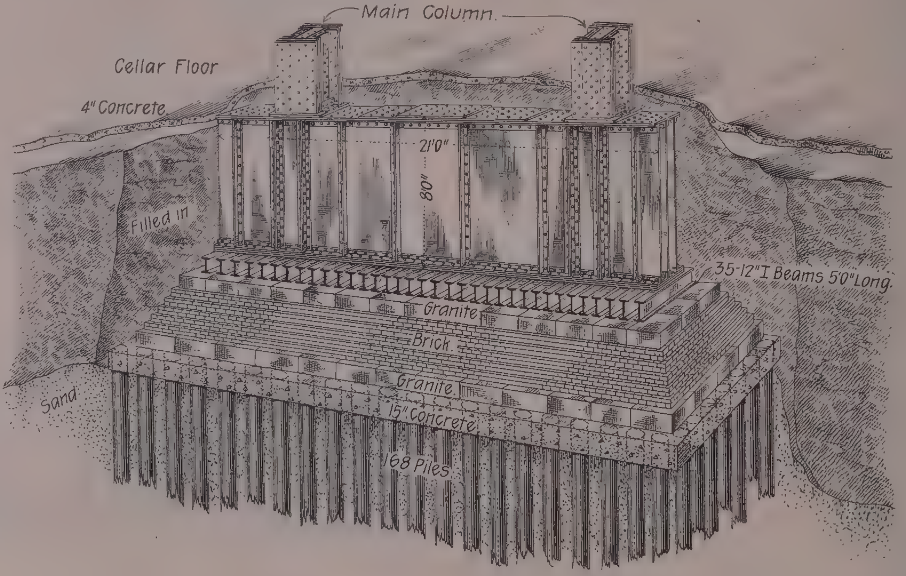
Until the introduction of steel cage construction, high speed passenger elevators, and the commercial distribution of electric light and power, all of which have taken place within the last twenty-five years, most of the classes of buildings mentioned were impracticable, unnecessary, and did not exist and the requirements of other buildings were generally satisfactorily met by the simple types and methods of foundation construction that have undergone little change for many years.

In several cities office buildings are now frequently 10 or 15 stories in height, in a few cities there are several from 20 to 25 stories high, and in New York, there are two buildings over 40 stories high. These develop concentrated loads of 3,000,000 or 4,000,000 lb. in a single column and their heights, of from 200 to 500 ft., are so great that the slightest irregularity of settlement in the foundation produces a greatly magnified variation from the vertical in the superstructure and causes great injury or destruction to the delicate and accurate machinery installed, besides settlement, and cracks and displacement of the beautiful cut-stone walls and lintels which would be great blemishes and would inspire public distrust sufficient to seriously impair the value of the building. It is therefore necessary that the foundations should be more than safe; they must be absolutely immovable within the smallest fraction of an inch; or that, if displacement occurs, it must be perfectly regular and uniform. As the cost of the important buildings, including their site, often varies between $1,000,000 and $10,000,000, the integrity of their foundations is of great financial importance and the present tendency is to take no risk whatever in insuring absolute stability by carrying their support to solid rock.

Where the rock is near the surface and above water level, as in some portions of New York, no particular difficulty or unusual expense is involved in securing unexceptionable foundations. Neither is there, where there is available a deep dry stratum of sand, gravel or dense clay, as in several other cities, which has a high bearing capacity and where the excavation can easily be made 20, 30 or 40 ft. below the surface to a depth not likely to be exceeded by future adjacent buildings. Where, however, the site is on filled land, often partly of rubbish and organic material, or where it is on quicksand, silt, mud or other soft wet material of small bearing capacity, great difficulty and expense may be involved not only in providing stable supports for the building, but in preventing injury or displacement to adjacent buildings. For these conditions entirely new types of foundations have been designed, and very interesting and ingenious methods of construction have been developed and perfected within 25 years by a comparatively small group of engineers, architects and contractors who have built the notable structures now standing in our principal cities.

The foundations on soft soil sites, including sand and quicksand, are of three types: 1. Those carried deep, usually below water line, to rock or hard stratum; 2, those supported on piles or their equivalents; and 3, those spread over the surface. The most important examples of all three types are found in New York and Chicago where in certain areas the conditions of the soil are bad and the buildings are taller than in other cities. In the banking district of New York, south of City Hall, much of the surface, especially near the river front, is made soil composed of earth, ashes, stone, rubbish and miscellaneous material underlaid with mud to a depth of 5 or 10 ft., below which is a stratum composed chiefly of fine sand with layers and pockets of true quicksand with occasional deposits of gravel and boulders to a depth of 40 to 80 ft. below the surface where gneiss rock is encountered in comparatively horizontal strata, sometimes overlaid with hardpan from 1 to 10 ft. in thickness or with two layers of hardpan separated by a few feet of sand or quicksand. The quicksand often contains a large quantity of micaceous material. is very fine and greasy and will flow very readily.

Ground water line in lower New York is nominally at about high-tide level, from 6 to 30 ft. below the surface, but of late years has been depressed in certain sections by the drainage from numerous deep cellars and the subway. In the corresponding district in Chicago there is an upper layer of black soil about 1 ft. thick, then 6 or 8 ft. of fine sand, 3 to 30 ft. of hard, stiff clay, 40 to 60 ft. of very soft clay saturated with water and finally 6 to 30 ft. of hardpan on solid rock. Ground water level is from 10 to 20 ft. below the surface. The upper layer of hard clay, if not disturbed, distributes moderate loads over the sub-stratum and is capable of supporting considerable pressure and is considered safe for loads of about 4,000 lb. per square foot. The soft clay underneath the hard crust is in a plastic condition and can support only very light loads. Foundations there are therefore generally supported either on the upper clay or are carried through the soft clay to the hard sand.



Pile Foundation, Pier, Grillage and Girder, Park Row Building.

Except for occasional very heavy machinery loads or monumental stone buildings, 6 or 8-story buildings were the maximum structures erected before the introduction of steel cage construction and when located on soft soil, their moderate foundation loads were easily diminished to safe unit pressures by wide masonry footings carried down a comparatively short distance below the surface of the soil, usually above ground water line. Or they were provided with pile footings capped with timber grillages just below ground water line so as to insure preservation of the timber. In the latter case if the piles did not reach rock or hard stratum their length was generally sufficient to develop friction great enough to sustain any loads which might be applied to them.

Sometimes the roof and floors were partly carried by interior wooden or cast-iron columns or even by masonry piers and sometimes these columns were replaced by solid masonry partition walls, but in all cases the exterior walls were of brick or stone, carrying their entire weight and a considerable part of the weight of the floors and roof. The walls were usually made with a minimum thickness of 8 to 12 in. in the upper stories, increasing with every successive story downward until they often attained a thickness of from 4 to 6 ft. of solid masonry in the lower stories and were seated on much wider footings of rubble masonry or concrete, usually carried just below the cellar floor to a depth of 10 to 20 ft. below the curb and rarely extending below ground water level.

In the oldest buildings, 4 or 5 stories high, the masonry footings were often replaced by grillages of very long, heavy timbers parallel with the wall and covered with transverse planks on which the brickwork or stone was built. Many of these have been dug up after 50 or 100 years and the timber buried just above or below ground water level has been found in perfect preservation. Where pile footings were used, the piles were seldom of great length or large diameter and sometimes extended considerably above ground water line. Sometimes the masonry was carelessly laid with small and irregular stones and was generally built with lime mortar so that in many cases the old foundations are of very poor quality compared with present standards.

In Chicago the construction of even the 6-story buildings in the business district is much more recent than most of those in New York, since many of them were built after the great fire less than 40 years ago. In these buildings there is room only for a basement and no cellar above ground water level and the footings of simple spread masonry are generally just below the basement floor and seated on the hard upper crust of clay. In some cases piles were used, but as they were generally comparatively short and small they did not reach to the hard stratum and since they broke up the hard clay crust and penetrated only partly through the soft plastic clay below without developing a large amount of friction in it, they may probably have often done more harm than good.

Attempts were made to distribute the total weights of a few heavy buildings uniformly over the entire areas occupied by means of thick concrete platforms continuous over the whole of the lots and virtually forming deep monolithic slabs at cellar floor level on which the masonry walls were started. The great irregularity of these concentrated loads produced large bending and shearing stresses, which in many cases broke through the thick mass of concrete, separating it into several parts and permitting large and irregular settlements in the superstructure which developed serious and even dangerous cracks in the masonry walls, as was notably the case with the heavy building of the La Salle St. Railroad Depot.

In the taller buildings both of New York and Chicago, to the difficulty of supporting their foundations on soft soil was added the very serious disadvantage occasioned by the great and rapidly increasing thickness at the feet of the walls and of the spread footings, which involved very large masses of masonry, greatly obstructing the basement and cellar, occupied valuable rental space, interfered with location of machinery and was very expensive to construct so that it became almost or quite a limiting factor in the height of the building.

About the first definite step in the development of tall buildings and the improvement of their foundations under difficult conditions was the adoption of iron beams, girders and interior columns, 40 or 50 years ago, which with the imperfect elevator and fire service then available extended the limits of construction to about 10 stories, as illustrated in New York by the Times, Mills, Union Trust and Equitable Buildings where, however, the outer walls still carried a large part of the floor and roof loads and were very massive in the lower stories with footings 10 ft. or more in width. The increased loads on the interior columns demanded careful investigation of the bearing capacity of the soil and that the piers should be rationally proportioned in accordance therewith, and they were carried on wide shallow footings or sometimes on piles.

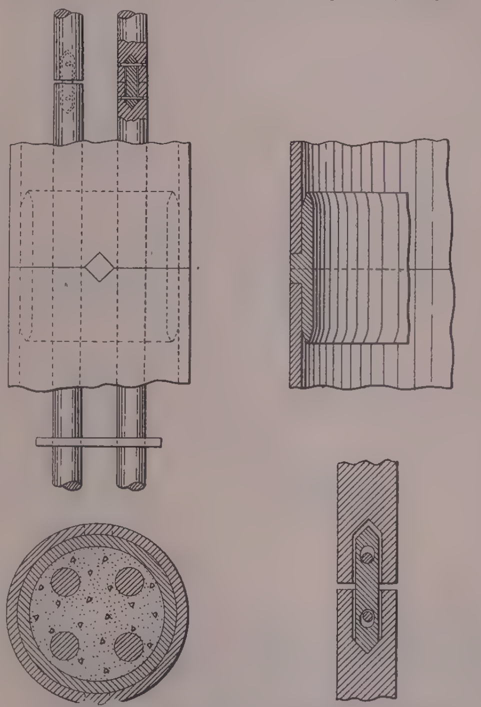
The second important step was the introduction of exterior columns carrying floor and roof loads but not supporting the wall masonry. When their foundations were separated from those of the adjacent exterior wall, difficulty was immediately encountered because of the eccentricity of their centers of gravity and those of the footings, and unsymmetrical construction, unbalanced pressure, and heavy stresses often resulted. In some cases, as in the Tarrant Building, the wall footings were interrupted to clear column footings and the system of large foundation piers for two or more balanced columns and cantilever and distributing girders transferring the column loads to the centers of gravity of the foundation piers were soon developed.

The third important step was the introduction of wall girders transferring the weight of the exterior walls entirely to the exterior columns in every story and completeing the essential development of the present steel cage construction. In this construction only the minimum thickness of wall masonry is required and a vast economy of cost, space and weight is secured in the lower story, which greatly reduces the foundation load and simplifies the arrangement and construction of foundation piers.

Tests of Site.—The design and construction of foundations for very heavy building is generally preceded by a subterranean exploration and sometimes by tests to determine the character of the underlying strata and its bearing capacity. Before the tenants vacate the old building, explorations can be made through sand and earth to a depth of 50 to 100 ft. by wash borings, made with double pipes sunk in short sections by an hydraulic jet and a light hammer. These borings can be made in the headroom afforded by an ordinary cellar, and although the results are negative rather than positive, the general indications of the character of the strata and of the position of the hardpan or bed rock are valuable and should not be neglected.

The bearing capacity of the soil is less frequently tested, but experiments are occasionally made on it both by direct loading and pile driving. In the former case the required pressures are so great that it is difficult to apply them except through areas so small that it is doubtful if the result secured should be accepted as proportionate for the large areas of the foundation piers. It has, however, been done in some instances and special precautions have been taken to provide as much as possible for the wide variation in scale. The usual method is to build a horizontal platform 3 to 6 ft. wide, supported on a center vertical post with a bearing surface of perhaps 1 sq. ft. on the soil, and to load the platform with pig-iron or other concentrated weight until a pressure of 5,000 lb. and upward is produced on the soil and the settlements due to successive increments of load carefully measured and recorded. When pile tests are made, the dimensions of the pile, weight and drop of the hammer and penetration for each blow are recorded and after the pile is driven to the required depth, a platform is built on it and loaded and settlements noted.

The New York building law permits a foundation load of 8,000 lb. per square foot on compact sand or gravel, 2,000 lb. on soft clay, 4,000 lb. on wet sand and clay, 6,000 lb. on dry loam, clay or fine sand, and 40,000 lb. each on well-driven piles 14 in. in diameter and 30 in. apart on centers, and permits a maximum pressure of 30,000 lb. per square foot on brick masonry piers on rock and 20,000 lb. on gravel. The Chicago building law permits a load of 3,000 lb. per square foot on mixed clay and sand and 4,000 lb. per square foot on pure dry sand 15 ft. thick.



Splice in Steel Tubes and Compression Bars in Special Piles.

Pile Foundations.—The foundations of many tall buildings are supported on pile footings which, in Chicago, are sometimes carried to hard stratum at a great depth. In other cases no attempt is made to reach the rock or hardpan, but dependence is placed on the compression of the soil made by driving them and on the frictional resistance developed on their surface. That a very soft soil is materially compressed by a large number of piles driven in it is obvious, and in some cases the compression is so great that, as in the Fisher Building, Chicago, it is believed to have materially changed its character and to have forced out a large quantity of water. Where many piles are driven close together definite limits of usefulness and capacity are reached, as was notably the case in the foundation for the new Chicago post-office, where the piles were so numerous and were driven so hard that the driving of the last ones caused an upheaval which forced those previously driven to rise several feet.

For some of the tall New York buildings, it was difficult to drive piles in the fine, dense sand and some of them could not be forced down more than 10 or 12 ft., and the adjacent disturbance was so great that it is doubtful if their use was advantageous, especially in view of the fact that adjacent buildings with wide footings seated on the surface of the sand at about the same level, but without any piles below them have proved equally stable with as heavy loads. In recent practice the tops of the piles are cut off square well below ground water level and are covered with concrete 2 or 3 ft. thick, supporting a grillage of steel I-beams, also imbedded in concrete that receive the concentrated column loads and distribute it over the group of piles. Sometimes, as in the Park Row Building, and in the American Tract Society Building, a brick pier is built on the piles and capped with granite stones, which in turn receive the grillage beams.

Where it is uncertain that the ground will be permanently saturated above their tops, wooden piles are not desirable on account of the possibility of decay and considerable progress has been made in the development of different types of concrete piles to replace them. Piles cast above ground in moulds and reinforced with longitudinal and transverse steel rods have been made and driven but have not been found well adapted to driving like wooden piles, with a hammer alone, but should be sunk with an hydraulic jet or with a jet and hammer combined. Several designs have been made with different types of reinforcement, including a continuous spiral of steel fabric and another design in which the exterior surface is fluted and a vertical hole is left through the axis for the insertion of an hydraulic nozzle by which the piles have been very successfully sunk.

Many concrete piles have been cast in place in the ground and are of two principal types. One of them is made by first driving a vertical pipe with closed lower end to the required depth and pulling it out a few feet at a time and filling the spaces thus vacated by successive portions of concrete placed before the exterior earth has time to enter the cavity. Another method is by the use of a conical steel mandrel of the required diameter and length of the pile which is first covered with a sectional shell of very thin sheet steel and driven in position. After the driving is completed the mandrel is collapsed and withdrawn and the shell, which excludes earth and water, is immediately filled with wet concrete in which reinforcement rods may be placed.

Special piles of small size and great strength have been driven under difficult conditions where heavy loads were to be carried and all disturbance of adjacent structures avoided. Short sections of steel tubes about 12 in. in diameter were successfully sunk by a pneumatic hammer and an interior hydraulic jet. In some instances they were made double with interior and exterior pipes fitting closely and breaking joints, and in other cases they were composed of single pipes connected by inside sleeves provided with horizontal spurs like trunnions to engage rectangular holes in the abutting ends of the pipe sections and eliminate the necessity of screwed joints.

After the tubes were sunk to rock or hardpan the interior was washed and pumped out and filled with cement mortar or concrete in which were placed vertical reinforcement rods which, when the length required, were also made in sections 15 to 30 ft. long connected by special tennon butt joints designed to provide clearance for assembling and afford full bearing in service. In these piles the full sectional area of all the steel in the pipes and in the rods as well as of the concrete filling is calculated in estimating the compressive strength of the finished pile which thus figures out very high.

Spread Foundations.—The Drexel Building, Philadelphia, and the World Building, New

York, are among the earliest of the steel office buildings and their columns were supported on inverted arches distributing the loads over continuous lines of footings in the column rows. In Chicago the effort to reduce the foundation pressure to the unit value allowable on the soft soil led to the construction of wide thin footings made at first with successive crossed tiers of T-rails imbedded in concrete and diminishing in length from the bottom upward. An early example was that of the Rand and McNally and Rookery Buildings, where rail footings were used not only for the columns but for the exterior walls. The obvious functions of this type of foundation led to its various designations of floating foundations, raft foundations or Chicago foundations.

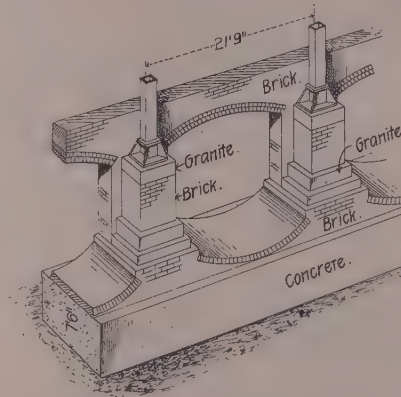
Soon after the introduction of this system, rolled I-beam sections became cheaper and more available and very soon replaced the rail grillages on account of their vastly greater bending moment and consequent reduction of weight and cost. A footing of any ordinary dimension is easily constructed with a grillage of I-beams usually from 10 to 18 in. in depth bolted close together with separators and seated on a layer of concrete a few inches thick. When the grillage is very wide, a second tier of deeper transverse beams acting as distributing girders is required to transmit column loads to grillage beams and usually consists of from 2 to 6 I-beams up to a maximum of 24 in. deep. In single-column foundations the columns are concentric with both tiers of beams and where the footing receives more than one column they are symmetrically arranged with the upper tier of beams and located so that the center of gravity of the combined group of columns is coincident with that of the footing.

The cast or riveted bases of the columns are seated directly on the distributing girders and the construction is so compact that its entire height is usually less than 4 ft. to the bottom of the column and enables it to be placed below the level of the cellar floor, thus saving a large amount of valuable space without excessive cost in excavation or construction. Where the loads are very heavy the upper and sometimes even the lower tiers of I-beams are replaced by riveted plate girders which may have any depth and strength desired. In some cases where very great shear was developed in the webs, the beams have been made with pairs of channels riveted together back to back with reinforcement plates between their webs.

Where special danger is not apprehended from future deep excavations alongside, the steel grillage type of foundation has become very popular for tall buildings and is used in New York, Chicago, Philadelphia, San Francisco and other cities. Prominent examples of it are the Marquett and Old Colony Buildings, Chicago, the Land Title Building, Philadelphia, the Wilkes Building, the Franklin Building and the St. Paul Building, New York, and the Spreckles and Phelan Buildings, San Francisco.

For very tall buildings it is often necessary to cover a large percentage of the area of the lot occupied by the grillages, and the inclination at first seemed to be to use very long I-beams and make the grillages continuous over the entire lot or over large sections of it. By this method excessive stresses are developed in the grillages by large variations in the column loads, therefore it was found more desirable to provide separate independent footings for many of the columns which facilitates proportioning them for uniform earth pressure irrespective of the column loads without involving unnecessarily high bending moments in the grillages. Columns are therefore now largely supported on separate footings or in groups of not more than three or four on the same footing, and care is taken to positively separate the grillages in many cases although they may all be set on the same continuous thin bottom layer of concrete which frequently serves more to protect the surface of the soil than to afford any appreciable distribution of load. Although the interior columns may be thus separated the conditions are different for wall columns adjacent to party lines and these are almost always balanced singly or in pairs, the latter especially at corners, with interior columns and supported on distributing or cantilever girders that permit them to be located unsymmetrically and eccentrically from the footings and yet deliver the loads to the center of gravity of the latter.

In New York buildings, the elevation of the grillage beams in the lower tier is often controlled by the ground water line and is seldom carried more than 2 or 3 ft. below it. At the maximum depth the excavation is usually drained by powerful pumps and the concrete laid on the smooth surface of the sand. In some cases where quicksand is particularly troublesome, low cofferdams of planks on edge or even of cement bags are used to separate small sections of the area which are successively concreted. Sometimes it is considered dangerous to do any pumping on account of the possibility of causing a flow in the quicksand and consequent undermining of adjacent tall and heavy structures and the surface of the soil is excavated as well as possible under water a foot or two in depth and the lower portion of the concrete is carefully deposited in it, and sometimes held down by heavy temporary weights until it develops strength to resist the upward pressure.



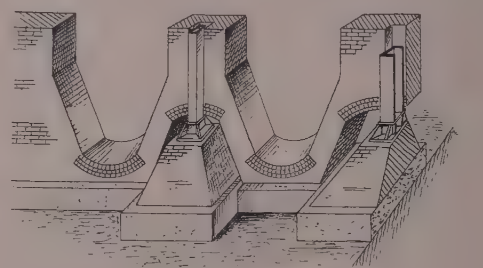
Foundation of Drexel Building.

Great care is taken in leveling the beams to set their flanges all in the same horizontal plane and special horizontal angles are sometimes provided for guides. Spaces are usually left, however, between the two tiers and between beams and the pedestals and the upper members are temporarily supported on shims or wedges and grouted to insure complete bearing on both surfaces. In cases of extremely heavy loads, the column pedestals are sometimes seated on the upper beams or girders with rust joints.

Foundation Grillages and Girders.—When the column loads are very heavy, the distributing girders are frequently triple web plate girders from 4 to 6 ft. deep and from 15 to 30 ft. long, riveted up complete at the shop with thick web plates and heavy flange angles thus attaining weights of 10 to 30 or 40 tons each. In some cases the flanges are connected by wide riveted cover plates thus combining the elements into one single member that may have such dimensions and weights as to render it difficult to handle. When it exceeds the capacity of the derricks installed on the work, it is usually lowered from street level on inclined skids or sometimes delivered to the bottom of the excavation by special tackles suspended from gallows frames or shear poles. Often the separate webs are only connected together by the column pedestals or by flange plates bolted on after they are placed in the building, thus reducing the weight of the pieces handled during erection.

In a few cases the girders have been replaced by trusses which although deeper have a somewhat reduced weight and can be easily shipped in sections so that the separate members can be handled at the site. An example of both types is afforded in the Franklin Building, New York, which has a superstructure about 100 ft. square and 160 ft. high above street level. The entire area of the general excavation was covered with a continuous layer of concrete about 1 ft. thick over the top of the fine gravel and sand. On this floor there were placed 23 separate rectangular grillages and 20 and 24-in. I-beams which cover about 80 per cent. of the entire area of the lot, and are assumed through the lower layer of concrete, to distribute over it a uniform pressure of 8,000 lb. per square foot.

Eight of the grillages support a wall column at one extremity balanced by an interior column at the other extremity, both of them seated on a truss or girder which serves both as a distributing and as a cantilever member. The other grillages have single columns located concentrically and supported in most cases on triple web girders 6 ft. deep and 16 ft. long, although a few of the lighter columns are seated on sets of four 24-in. transverse I-beams. The shorter cantilevers are triple plate girders as already mentioned, but the longer ones are massive pin-connected trusses having maximum dimensions of about 32½ ft. long, 16 ft. deep and 3 ft. wide, weighing as much as 60,000 lb. each. The maximum weight of the plate girders is about 80,000 lb.

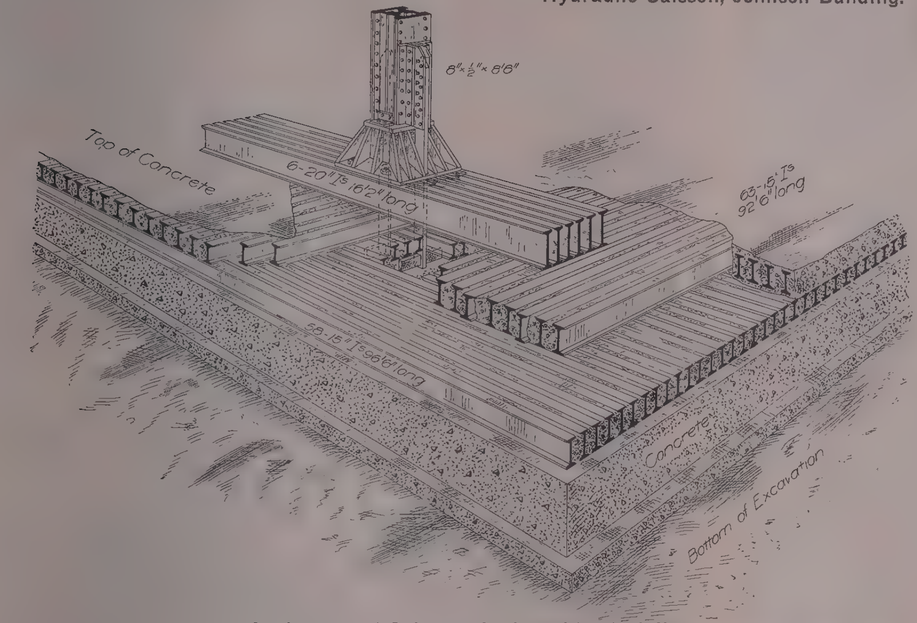


Isolated Wall Column, Tarrant Building.

The 26-story St. Paul Building, New York, has plate girder grillage foundations on a continuous 12-in. bed of concrete at ground water level covering the bottom of the excavation and supported on the fine, dense sand, which under an estimated uniformly distributed lead of about 6,000 lb. per square foot settled less than ⅝ in. in the first year after the erection of the building.

In New York, few or none of the tall buildings have settled more than a fraction of an inch, but those built over the deep stratum of plastic clay in Chicago have shown much greater settlement. The Home Insurance Building there, which is 159 ft. high, has wide solid masonry footings resting on the hard upper crust of clay and its erection was commenced 2½ in. above required grade and eventually settled an average of 2¼ in., with a variation of only 11/16 in. between any two points. In view of anticipated future settlement, provision has been made in two or more important buildings in New York and Chicago for maintaining their level by mechanical appliances and their column bases have been arranged with spaces in which it is possible to temporarily seat powerful hydraulic jacks, lift them to correspond with the settlement of the building and permit the insertion of permanent steel bearing plates under their bases.

One of the most notable grillage foundations is that of the 75 x 75-ft. Spreckles Building, San Francisco, which has a main portion, 15 stories high, surmounted by a dome rising to a height of 310 ft. above the sidewalk. The building is of steel cage construction with masonry exterior walls and has successfully resisted severe earthquake shocks, in anticipation of which the foundation was specially designed. A 98 x 102-ft. pit was excavated 25 ft. below street level and the dense wet sand of the bottom was covered with a continuous 96 x 100-ft. layer of concrete 2 ft. thick. On this was set a tier of transverse 15-in. I-beams 2 ft. apart made in three or four sections each, web and flange spliced to form continuous girders. Concrete was filled solid between and around the beams and the corresponding tier of longitudinal beams was set across their top flanges and filled with concrete, thus forming a monolithic reinforced concrete platform about 4½ ft. thick with an area about 70 per cent. greater than that of the floor of the building. This was calculated to distribute the entire load of the building at a uniform pressure of about 4,500 lb. per square foot on the surface of the sand. On this platform are placed 28 sets of distributing girders each composed of six 20-in. I-beams receiving the cast pedestals of one or two main columns. In the base of each pedestal there are two holes, through each of which an 8 x 1½-in. vertical steel bar about 9 ft. long passes and is riveted at the upper end to the column. The lower ends of the bars pass between the webs of the grillage beams and are secured to them by keys, thus affording ample anchorage for any possible uplift.

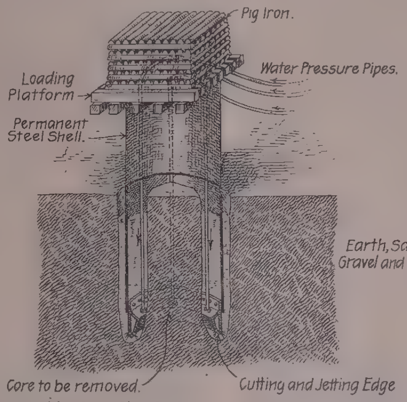


Anchorage of Columns in Spreckles Building.

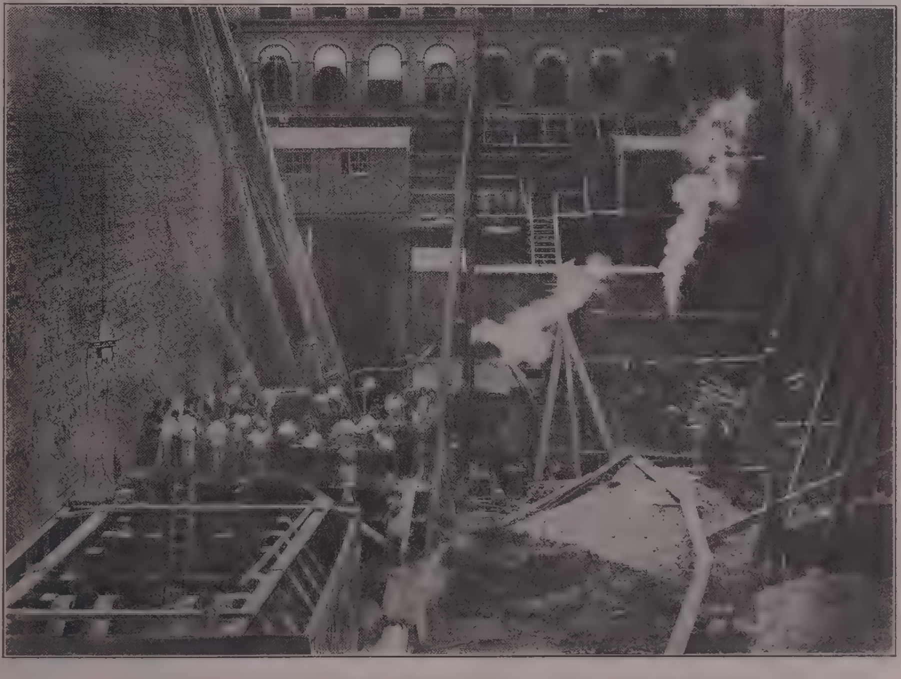
Reinforced concrete has been used for extended surface footings instead of I-beam grillages, as in the Bourne Building, New York, and enables the column support to be a single monolithic mass, combining grillage and distributing beams. The reinforcement is made with crossed tiers of rods easily providing the exact proportion of steel required, and often procured more quickly and cheaply than grillage beams.

Open Caissons.—Wherever the conditions are such that the foundations of a heavy building can be carried without great difficulty or expense to solid rock, no other method of construction should generally be considered. Under favorable conditions, when the depth of the rock is not great and water or quicksand is not encountered, excavations can be made in open caissons or cofferdams, and foundation piers can be built in them at moderate cost. The same method can be pursued in wet ground when pumping is permissible. If there is much quicksand, or if the excavation goes below the footings of heavily loaded adjacent foundations, the work may become very hazardous and require difficult and expensive operations to carry out successfully.

The essential requirement is to make an accessible excavation to hard stratum, prepare, inspect and approve there a suitable bearing and build on it a solid masonry pier, operations which are often made very difficult by treacherous soil, the occurrence of large quantities of water and the danger of injury to adjacent structures. Several methods have been developed for executing this work in different locations where the character of the soil and the local conditions vary.



Hydraulic Caisson, Johnson Building.

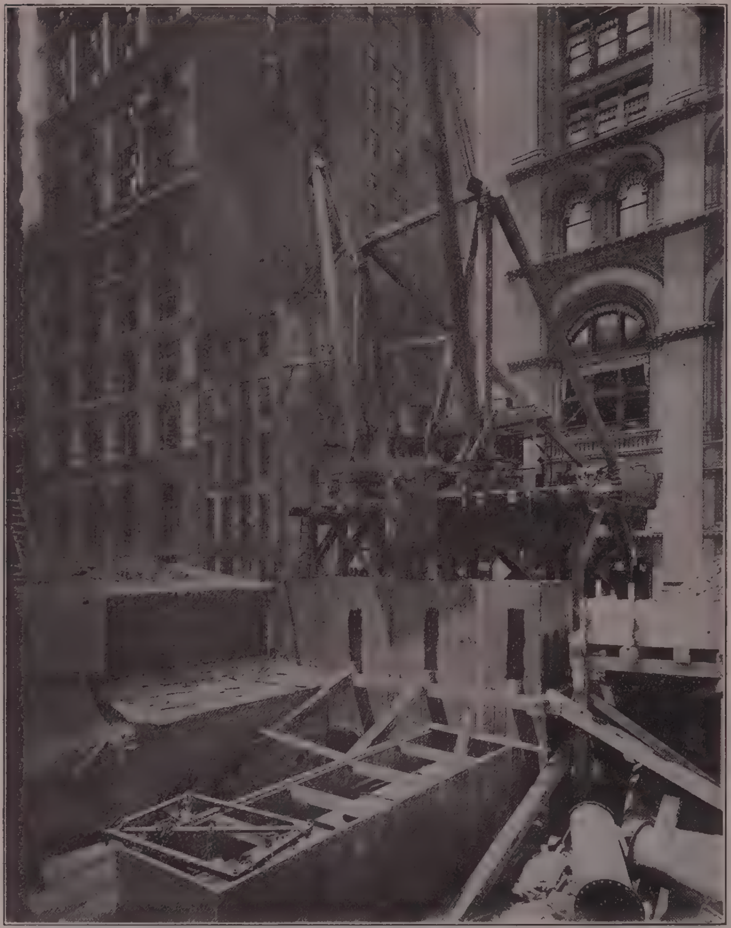


First Application of Pneumatic Caissons to Building Foundations.

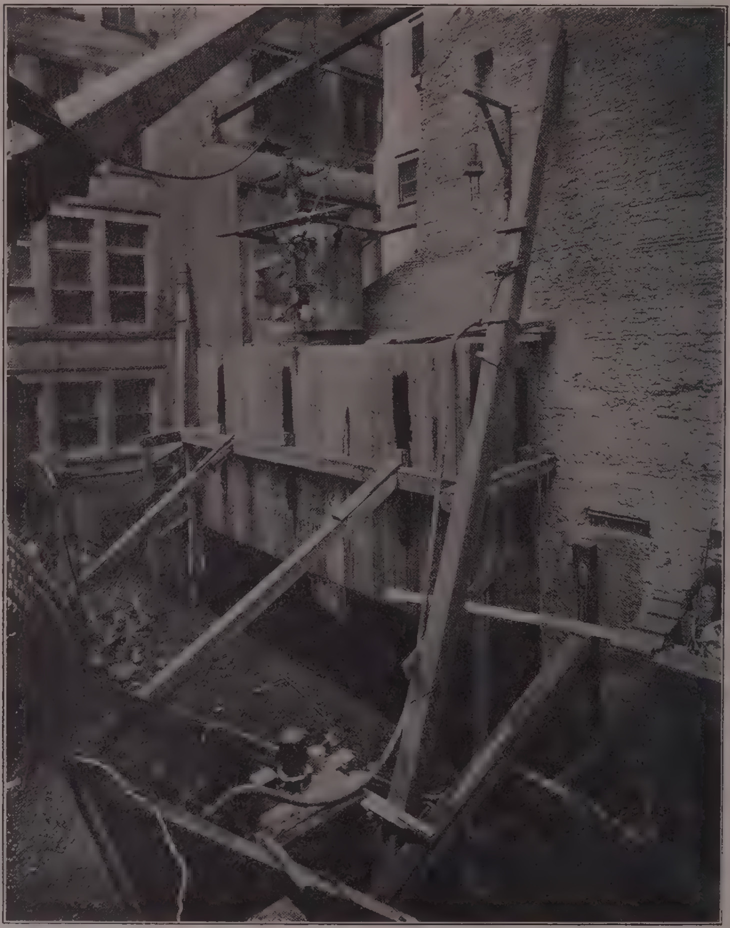
In some cases cofferdams of interlocking steel sheet piles have first been driven to rock, as for the Hoffman House extension, New York, and open excavation made in them. This process becomes very difficult when the depth is great or when many large boulders occur, and it is sometimes objectionable to operate a pile driver before sinking them, and very few steel sheet piles have positive water-tight joints, but must depend on silting or splining. When steel piles are available that have an absolutely water-tight joint and can be driven with less injury from boulders and other obstruction, their use will often be very advantageous for such work.

In Chicago concrete foundation piers for heavy buildings have been successfully carried to the deep, underlying hard stratum by a system of excavation analogous to standard tunneling and shaft sinking operations. Horizontal steel rings having the required diameter of the excavation are made in sections bolted together through inside flanges and assembled at the bottom of the pits. Outside of them are driven sets of short, narrow, vertical poling boards forming complete cylindrical sections of stave lining. They are driven with mauls as the interior excavation progresses, and are inclined slightly outward from the vertical at the bottom so that a second ring can be assembled there and the next set of poling boards driven between it and the first set, and so on. Little trouble is encountered from the water, and the plastic clay is easily excavated and is generally hoisted in buckets operated by windlasses, a row of which are simultaneously operated by a continuous rope drive from a single engine. Sometimes the bottom of the excavation is undercut or expanded to give a wider bearing and after the surface is satisfactorily prepared, the well is filled solid with concrete.

Hydraulic Caissons.—A few deep rock foundations, including those of the Johnson and the Meyer-Jonassen Buildings, New York, have been sunk by the hydraulic caisson method, which consists substantially of sinking steel cylinders without interior excavation, by means of hydraulic jets. Riveted steel cylinders from 5 to 13 ft. in diameter and 27 ft. long were set up vertically in the required locations, and their lower edges were fitted with annular cast-iron cutting edges of hollow triangular cross section with numerous small inclined perforations in the lower edge and connected to vertical pressure pipes with flexible hose coupled to a powerful force pump. The cylinder, being heavily loaded, the pump was put in operation, and the numerous jets at the foot of the cylinder scoured away the soft material sufficiently to excavate an annular trench in which the cylinder descended through clay and quicksand to solid rock. The hydraulic pressure was then discontinued, the cylinders pumped out and the interior core excavated by hand work. In some cases the rock was overlaid with tough clay which sealed the bottoms of the cylinders, and in other cases where the surface of the rock was irregular, it was necessary to drive short interior sheet piles to close the lower edges. The cylinders were sunk at a rate sometimes as rapid as 8 in. per minute. The bottom was covered with 2 or 3 ft. of concrete, on which a solid brick pier was built inside the light steel cylinder which temporarily served as a cofferdam.



Cofferdam, Caisson and Air-Lock, Stock Exchange Building.



Wall Column Caisson Used in the Hanover Bank Building.

Nearly 100 piers for the walls and columns of the City Hall, at Kansas City, Mo., were built in open cylindrical steel caissons $4\frac{1}{2}$ ft. in diameter, sunk 50 ft. to rock through clay or a rubbish fill. The cylinders were sunk by an excavating auger operated by steam power and were filled solid with brickwork in which, for the heaviest loads, a Z-bar reinforcement column was built and seated on the solid rock.

Pneumatic Caissons.—The great desirability of eliminating all possibility of settlement, no matter how small, from the foundations of very tall buildings has developed a very strong tendency to carry their solid masonry piers to rock and the depths of the latter, combined with the character of the overlying strata, the large quantities of ground water, and the number of heavy existing buildings, with comparatively weak and shallow foundations has made the problem a very difficult one in the lower part of New York City, where, in many cases, the methods already described have been considered dangerous, impracticable or otherwise unsatisfactory. An entirely different method has, therefore, been adopted, and within a few years has become highly developed, and, together with an extremely efficient and rational way of underpinning adjacent buildings which, at best are more or less threatened by the construction of the deep new foundations, marks an important epoch in construction and greatly increases the magnitude, safety and scope of difficult foundation work.

For a comparatively long time the principle of the diving bell has been successfully applied to the construction of bridge piers in soft ground and under water, by the pneumatic caisson process, but the method was not applied to the foundations of buildings, and probably was not justified for such purposes until the construction in 1893 of the Manhattan Life Insurance Building, on lower Broadway, New York. This is one of the earliest of the tall steel cage office buildings, and is an 18-story structure, with a front of 67 ft., a depth of 122 ft., and a total height of 350 ft. from the curb to the foot of the flag-staff. The outer walls are of brick, limestone and terra-cotta, carried by the steel framework, which is supported by 34 cast-iron columns, which together sustain a total estimated load of about 60,000,000 lb., an amount equivalent to over 7,000 lb. per square foot of the entire area of the lot occupied.

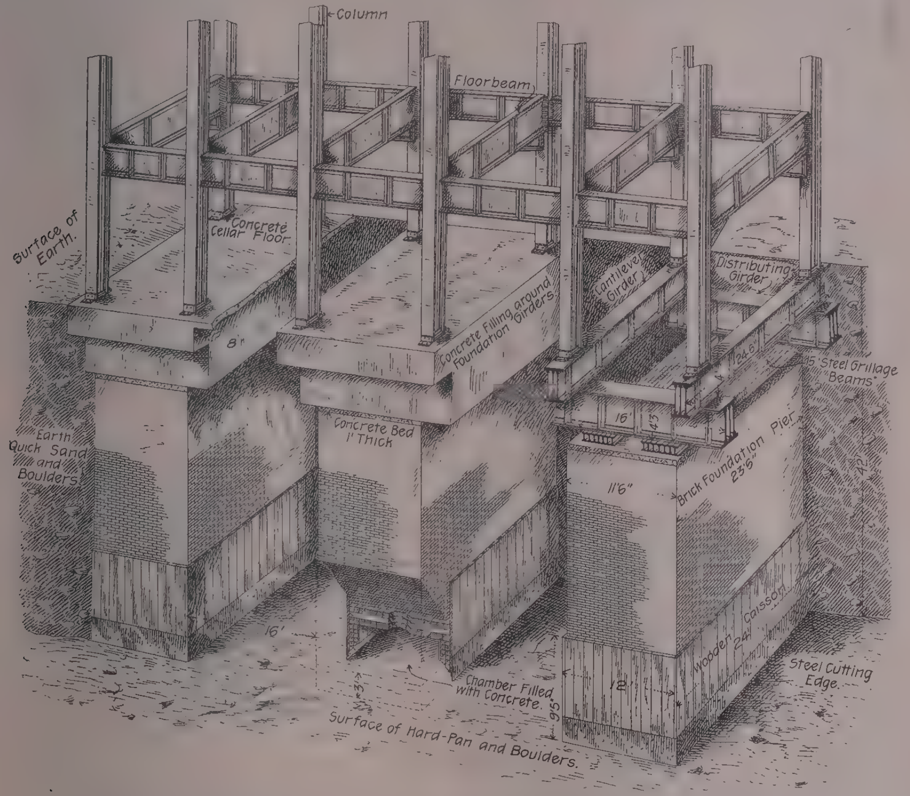
The soil consisted of about 54 ft. of mud and quicksand overlying the rock, and containing a large quantity of water, which flowed freely through it up to ground water level, about 22 ft. below the Broadway curb. Piles, if driven as close together, over the entire surface of the lot, and loaded as heavily as permitted by the building law, would not have had sufficient capacity for the whole load, and it was decided to carry masonry foundation piers to rock by the pneumatic caisson method. Nine rectangular caissons were, therefore, located at the corners of the lot and intermediately between them on the long side, and these, together with four circular caissons and one small pile footing, were arranged to provide foundations for the main columns.

The caissons varied from a diameter of 9 ft. 9 in. to a width of 11 ft. by a length of 36 ft., and were sunk to a maximum depth of about 34 ft. They were made of steel, with heavy I-beam decks, knee-braced to the cutting edge, and the larger ones were delivered in sections and assembled, riveted and caulked in the required positions. They were sunk in an average of eight days each, with a maximum air pressure of about 15 lb., and much of the soft material was removed by the wet blow-out process. The surface of the rock under the caissons was leveled and dressed, the working chambers were filled with concrete and the brick piers above them built inside the permanent steel cofferdam. The substructure contains about 1,260 cu. yd. of concrete and 3,400 cu. yd. of brickwork, and cost about $150,000, or less than 9 per cent of the estimated total cost of the building.

From one to four columns were located over each pier, and were carried on distributing or cantilever girders, which thus transmitted their loads to I-beam grillages seated on the brickwork. This system of loading was somewhat unusual in that the cantilevers were transverse girders continuous across the full width of the building and carried four columns each. They were made with four webs, $7\frac{1}{2}$ ft. deep at the ends, and had lower flange bearings limiting the points of application of their loads on the grillages.

The next pneumatic caisson foundations were those of the 21-story American Surety Building, New York, built in 1894 under conditions similar to those of the Manhattan Building. Here there were 13 rectangular steel caissons each carrying two or four columns which were sunk through quicksand and other materials to rock at a maximum depth of about 60 ft. below the surface. They were riveted and caulked complete at the shop and the brick piers on their decks were built above the bottom of the pit as fast as or faster than the caisson descended, thus obviating the necessity of cofferdams around them. The air shafts were made with oval cross sections connected by interior flanges and removed and the spaces left in the brickwork filled solid with concrete.

All of the column loads were transmitted to the piers through I-beam grillages on top of the brick work and several of the exterior piers supported triple web cantilever girders carrying wall columns balanced by interior columns. The respective loads and lever arms of the anchor and cantilever ends of these girders were such that their moments were in stable equilibrium for the finished building, but in order to provide for any possible temporary variations in their proportions during construction the theoretically possible temporary stresses were provided for by permanent anchorages at the inner ends of the cantilevers. The ends of the top flanges of the girders were provided with convex cast-iron saddles engaging the loops of U-shaped 8 x ¼-in. eye-bars joining the upper links of double vertical eye-bar chains built solid into the pier masonry and connected at the lower ends to reaction girders just above the decks of the caissons, thus utilizing the entire mass of the brickwork pier as a counterweight. The fulcrums of the cantilever girders on the distributing girders were formed with solid tiers of transverse steel bars 4 in. square which definitely locate the application of the load.


Column
Floorbeam
Surface of Earth.
Concrete Cellar Floor.
Concrete Filling around Foundation Girders
Cantilever Girder
Distributing Girder
8'
24'6"
15 Steel Grillage "Beams"
16'
4'3
Earth Quick Sand and Boulders
Concrete Bed 1' Thick
11'6"
Brick Foundation Pier 23'6"
4'2"
16'
3'
Chamber Filled with Concrete.
9'5"
12
Wooden Caisson 24'
Steel Cutting Edge.
Surface of Hard-Pan and Boulders.

Pneumatic Caissons, Piers and Substructure Girders, Gillender Building.

With one or two recent exceptions, the use of pneumatic caissons for foundations has been confined almost exclusively to New York buildings, and the details of their design and the methods of sinking them have been greatly modified and improved, subsequent to the examples above described. Some of the most important improvements have been in the reduction of the size of the caisson, in the substitution of wood for steel, in the use of concrete instead of brick for the piers, in the elimination of the cofferdams, in the use of removable air-shafts, in the details of the material locks, in the use of steam from a central plant and in making permanent connections between adjacent caissons after sinking so as to form a continuous water-tight wall of separate units.

Wooden Caissons.—Rectangular wooden caissons, built at first to correspond substantially with the steel caissons, were made of dimensions enabling them to be completed at the contractors' yard, and transported on trucks to the site of the building, where they were handled by single derrick booms. The air locks first used necessitated a considerable delay for unhooking the bucket from the hoisting line every time that it passed in or out, and a great advantage was gained when the horizontal upper door of the air lock was made with two leaves engaging a stuffing box, through which the hoisting rope passed. This device enabled the bucket to be continuously attached to the hoisting line and practically doubled the speed of operation. Circular caissons were made, with vertical hooped staves extending far above the caisson roof and forming the walls of permanent cofferdams. In some cases the cutting edges were left higher on one side than on the other, thus determining the location of any escaping air and facilitating the control of the caisson in sinking.

Later the walls of rectangular cofferdams were bolted to horizontal angle iron frames, and the steel air shafts were made collapsible to facilitate their removal after the concrete had set around them. In sinking the earlier pneumatic caissons much time and expense was involved in the handling of very large quantities of pig-iron or kentledge used to load them sufficiently to overcome the enormous frictional resistance on their exterior surfaces. Later this disadvantage was much reduced by casting the metal in large rectangular pieces of uniform size, or packing it in strong boxes, which were much more rapidly and easily handled and piled by the derricks. Recently their use have been almost eliminated by the present method of building the piers above ground and utilizing their great weight to sink the caissons.

In the foundations for the United States Express Building, the Singer Building extension, the City Investing Company's Building and the Hudson Company's Building the rectangular pier caissons were sunk, as in the other cases, through quicksand, clay, gravel and even hard pan to the solid rock, at depths of from 50 to 80 ft. below the surface. Great ingenuity and economy were attained in the construction of the rectangular caissons, which were very simply and rapidly made with four vertical wooden walls and a very light temporary wooden roof. In the United States Express Company's Building the rectangular wall column caissons had a uniform width and height of 12½ ft. and 6 ft., respectively, and varied in length from about 25 to 35 ft., having a maximum weight of about 10 tons, easily handled by the traveling derricks, by which they were unloaded and placed in the required position in the bottom of the excavation. The walls were made with solid courses of 6 x 12 and 8 x 12-in. timber and were connected at the top by transverse horizontal angles 3 ft. apart. Temporary 1⅞-in. tongue and groove boards were supported on the horizontal flanges of the angles and were enclosed by molds 8 ft. deep, made with 2-in. vertical boards and outside rectangular yokes, tied together by permanent transverse screw rods.

The lower section of the temporary collapsible steel air-shaft was fastened to the roof boards, and the latter were covered with 6 in. of rich concrete. After it had set sufficiently to develop some bearing strength more concrete was added, forming a thicker slab, which in four days was strong enough to carry the weight of wet concrete, filling the remainder of the mold. When the concrete was hard enough the mold was slipped upward on it and refilled, and so on until the pier was completed. In the meantime men inside commenced the excavation under atmospheric pressure, and as the tall and narrow pier descended it was guided, and its stability was assured, by rectangular horizontal frames enclosing it and braced by inclined struts and bearing on vertical strips attached to the face of the concrete. When the cutting edges descended below ground water level, air locks were placed on the shafts, and the work was continued in the usual way under pneumatic pressure.

Among the most important pneumatic caisson foundations, those for the Mutual Life Insurance Building are notable for their massive character, the depths to which they were sunk and the lavish expenditure involved in the construction of the substructure. The 15-story columns are supported on circular and rectangular steel piers sunk with steel caissons through quicksand and a thick stratum of hard pan to rock at a maximum depth of 100 ft. below the surface and 75 ft. below ground water level. Both the steel cofferdams and the steel shafts of the wall caissons were permanent structures. It was admitted that the sub-structure and the underpinning of adjacent buildings cost $700,000, and it is probable that the total cost of the substructure considerably exceeded that sum.

A remarkable record for rapidity was made in the construction of the pneumatic caissons foundations of the 21-story United States Realty Company's Building, where 87 pneumatic caissons were sunk to rock at an average depth of 75 ft. below the surface in 60 days. As many as 14 caissons were under pressure simultaneously, and 57 were sunk in 30 days at a maximum rate of as much as 2 ft. per hour.

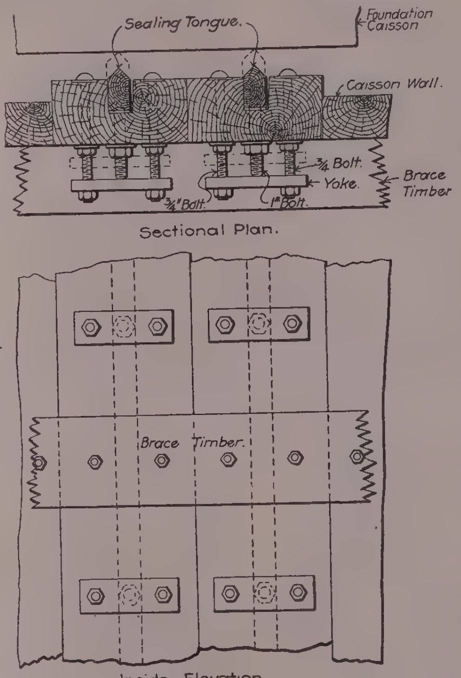
The foundations of the Gillender Building are very remarkable for several reasons; the main roof is over 200 ft. above the street, and the total height of the steel framework is about 310 ft., while its narrowest width is less than 22 ft. on centers of columns. The framework has only 12 columns, arranged in two longitudinal rows and grouped in sets of four, each of which is supported on a single pneumatic caisson pier, narrower and shorter than the distances between the columns, so that the latter overhang it in both directions. The total estimated weight of the building and conents is about 9,000 tons, which produces a pressure of about 12 tons per square foot on the footings of the caissons, which cover about three-fifths of the total area of the lot, 1,852 sq. ft. The rectangular caissons are of massive timber construction and the excavation in them was carried several feet below the cutting edge into the hard pan and the space filled in the usual way with concrete. The brick piers above the caissons were built in permanent wooden cofferdams and are capped with grillages of full-length transverse I-beams on which are seated at each end triple web longitudinal distributing girders longer than the caissons so that they overhang at both ends and really form double balanced cantilevers. Similar transverse girders are seated across both ends of the top flanges of the longitudinal girders, also overhanging at both extremities and carrying the columns at their ends. The lower flanges of the grillage beam are just above ground water level and the spaces between and around them and all of the girders are filled solid with concrete levelled off just above the top flanges of the upper girders in the plane of the cellar floor.

Continuous Caissons. In a number of important buildings the excavations have been made deep enough to permit of the construction of three or four stories below the surface of the ground and thus involve retaining walls of enormous strength and special water-proofing to resist the tremendous exterior pressure of the quicksand and water, under a hydrostatic head of sometimes more than 50 ft. In several cases the required result had been accomplished by supporting the wall columns on comparatively long and narrow rectangular pneumatic caissons sunk very close together end to end and afterwards joined so as to form a continuous wall or dam enclosing the site of the building and carried down through the water-bearing stratum to foundations on the rock or hard sand. The Commercial Cable Building, the Blair Building, the Mutual Life Insurance Building, the United States Express Building, and the Stock Exchange Building are all examples of this type of construction, and present several radically different methods of accomplishing the difficult task of forming a satisfactory bond between the caissons and piers after the completion of the latter.

The first of this group was the 21-story Commercial Cable Building with caissons from 4 to 10 in. apart sunk, in 1896, to rock at a depth of about 40 ft. below the surface. After the cofferdams were concreted a 3-in. vertical pipe was sunk to rock between them by means of an interior 1½-in. hydraulic pipe with a ½-in. nozzle and the latter was withdrawn and replaced by clay cylinders rammed down by a heavy iron plunger driven by a pile-driver hammer. As the clay was forced out of the open bottom of the pipe, the latter was gradually raised and the clay displaced the quicksand filled all of the space between the cofferdams and exerted a pressure sufficient to break some of the bolts in the latter and form a wall strong enough to resist the exterior pressure until the permanent brick wall was built inside. A similar method was used for the Mutual Life Building, but an entirely different one was adopted for the work on the Stock Exchange.

The Stock Exchange Building has a cellar floor 54 ft. below the curb and 42 ft. below ground water level, and it was decided to build the exterior caissons first and connect them so as to form a continuous wall around the lot excluding the ground water and enabling the interior to be drained by pumps so that the foundations there could be carried down in open cofferdams. The exterior caissons had a uniform thickness of 8 ft., an average height of about 50 ft., including the permanent wooden cofferdams continuous with their walls, and were from 24 to 30 ft. long. They were of special construction, with removable domed steel roof plates and vertical wall planks and were delivered at the site in complete sections weighing about 30,000 lb. each.

They were sunk to rock at an average depth of about 50 ft., and the cutting edges were puddled with clay and a 6-in. layer of concrete was rammed over the bottom and allowed to set under pneumatic pressure, balancing the outward hydrostatic pressure due to the 40-ft. head of exterior ground water. The caissons were sunk very close together with great accuracy, and when they were concreted semi-circular vertical shafts, 4 ft. in diameter, were formed at the ends of the cofferdams and smaller ones on the same line in the working chambers. Afterwards men entered the shaft and removed the center planks, thus throwing the two adjacent shafts into one of elliptical cross section, which was filled with rammed concrete, making a massive water-tight key which efficiently bonded the two caissons together.



Sectional Plan.

Inside Elevation

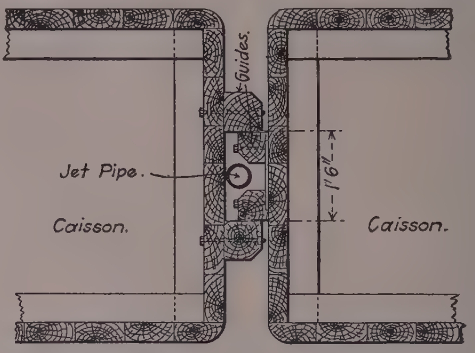
Caisson Connections, Bank of State of New York.

In cross sections the keys were about 4 ft. wide and 5 ft. long, with semi-circular ends connected by the neck formed by the end walls of the caissons and thus having an outline which closely resembled the section through the longitudinal axis of a rivet with two button heads. Before these shafts were connected horizontal holes were bored through the adjacent walls of the cofferdams and caissons and bolts were inserted and drawn up as tight as possible, making the openings between the planks so small that they were later easily caulked with oakum when necessary.

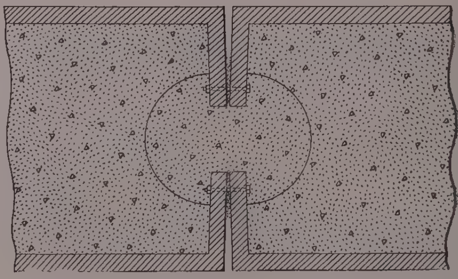
The interior caissons were sunk long before the main excavation was completed and temporary cofferdams were carried up to the surface of the ground to exclude the earth and enable the steel columns to be erected before the excavation of the earth caused too great an unbalanced pressure on the opposite faces of the wall caissons. After a large weight of steel had been assembled and considerable stress developed in the lower sections of the columns, the excavation was continued and great care was taken to brace the wall caissons to them and across the full width of the building, with special distributing girders and adjustable connections to secure positive bearings on the faces of the caissons.

The large rectangular wooden caissons for the wall columns of the Bank of the State of New York Building were sunk with intervals of from 4 to 14 ft. between their adjacent ends, and it was afterwards decided to sink small rectangular wooden caissons between them so as to form a continuous tight wall extending down to the surface of the rock. The lengths of the small caissons were about 3 in. less than the respective distances between the ends of the large caissons, and it was necessary to provide a simple and adjustable device to positively close the irregular spaces and exclude the very fine sand which it was found flowed almost like water through the smallest openings when the heavy exterior pressures were unbalanced by interior excavation.

A pair of 2 x 3-in. full-length vertical grooves about 12 in. apart were provided in the center of each end of the new caissons, and in them were fitted 2 x 6-in. wooden strips or splines projecting like tongues, and having the outer edge beveled at 45 deg. on each side to a sharp corner projecting toward the old caissons. Horizontal set screws 1 in. in diameter, and about 2 ft. apart vertically, engaged, at their outer ends, bearing plates on the tongues, and at the inner ends projected through the caisson walls, where they had a nut and washer bearing, and continued beyond the latter to end friction bearings against transverse steel yokes secured by horizontal tie bolts to the walls of the caisson. When the caissons were sunk the strips were forced back in the slots and afterwards the screws were operated to force them out normal to its face until their sharp bevels engaged, and were driven into the timber in the face of the adjacent old caisson.



Caisson Connection at No. 42 Broadway.

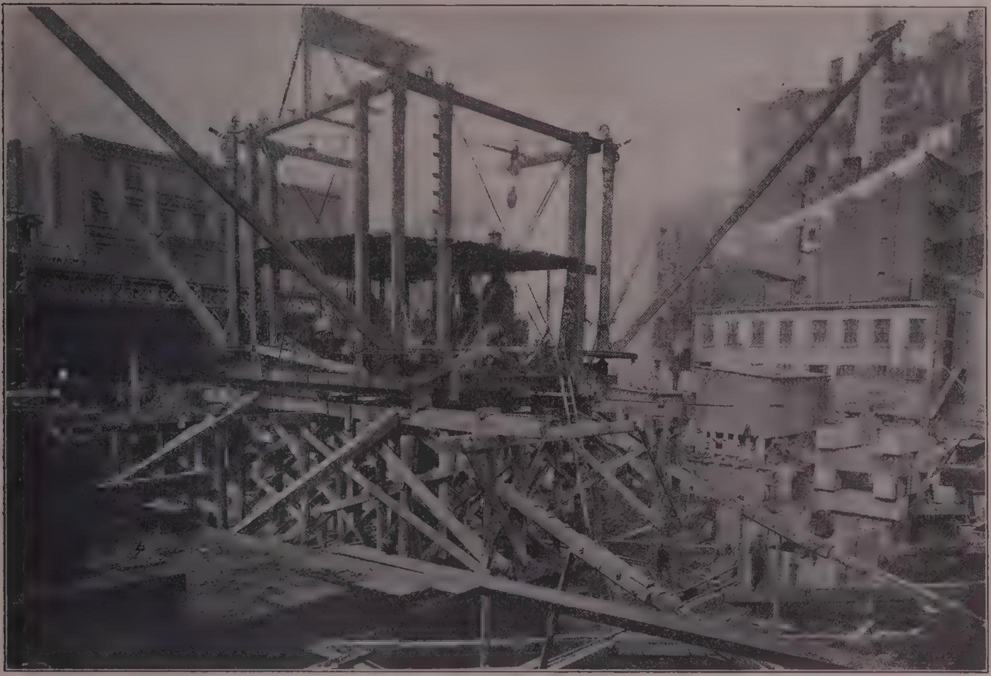


Wall Caisson Connection, Stock Exchange.

In a subsequent job executed by the contractors for the Bank of the State of New York, the caissons for the foundations of the office building at No. 42 Broadway were joined in a different manner to secure the water-tight enclosure of the lot. These caissons had a uniform width of 5½ ft. and length varying from 13 to 28 ft. Pairs of caissons were sunk simultaneously with the space between them about 2 ft. longer than the length of the third caisson, which was eventually to occupy that space.

When the intermediate caisson was sunk, its end walls were provided with a pair of 6 x 8-in. vertical guide timbers, countersunk bolted to it 2 ft. apart. After the intermediate caissons were sunk and concreted a pair of 6 x 6-in. vertical timbers spaced 8 in. apart in the clear and countersunk bolted to transverse steel tie plates, was sunk in the rectangle enclosed by the guide timbers and the adjacent walls of the caissons, by means of a 4-in. jet pipe attached to it.

The sinking was assisted by the static load of a 2,000-lb. pile driver hammer seated on the upper end of the timbers and enabling them to be carried down to hardpan and make a close joint all the way with the guide timbers. The water was blown out of the jet pipe by compressed air, the pipe was extended 30 ft. above the top of the caissons and filled to overflowing with Portland cement grout, lifted 2 or 3 ft., refilled with grout, lifted again, and so on until the joint was filled.

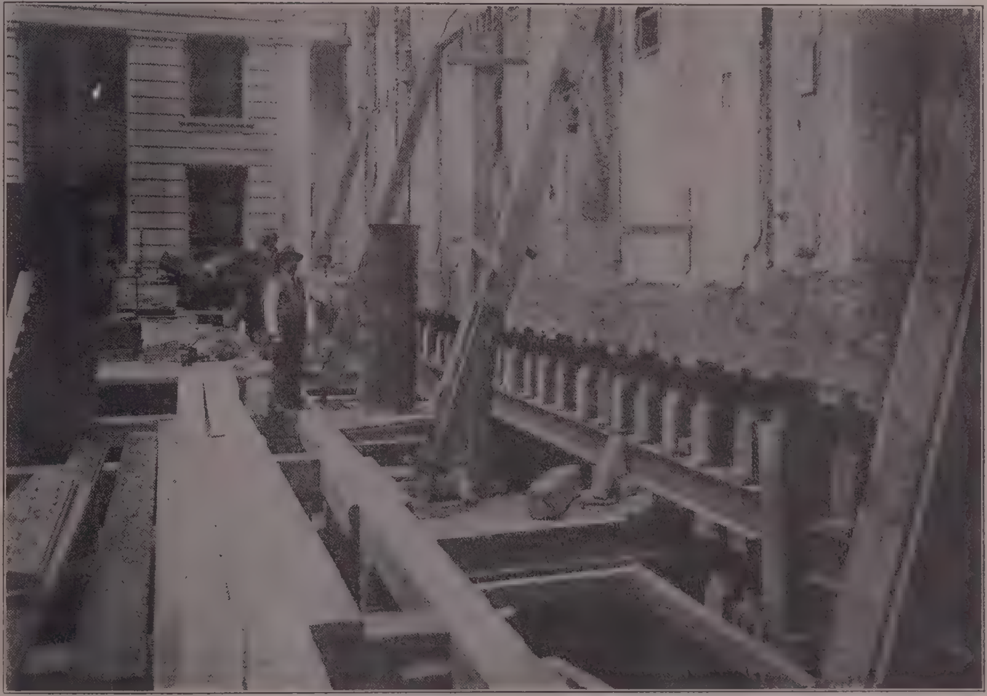


Falsework, Bracing and Traveler for Substructure Work on United States Express Building, New York City.

The latest type of caisson joint was that used for the United States Express Co.'s Building, where the wall piers have a uniform width of 64 in., are from about 20 to 35 ft. long and were sunk through water and quicksand to rock at an average depth of 41 ft. with simple rectangular wooden caissons, from 6 to 11 in. apart in the clear. Compound wooden sheet piles wide enough to cover the space between two adjacent piers and overlap them so as to take bearing on their longitudinal faces were driven between each pair of caissons, and were stiffened and reinforced by vertical ribs on their inner surfaces between the ends of the piers.

Jet pipes were sunk at each edge of each vertical pipe in the corner formed between them and the face of the pier, and grout was forced through them to seal the joints between the piles and the piers. After the piers were thus connected, the material between them was excavated by men working in shafts formed by vertical recesses 2 ft. wide and 8 in. deep moulded in the ends of the piers and making, together with the clearance between piers, a space 24 in. or more in width. As the excavation proceeded it was possible to caulk the sheet pile joints where necessary. As the recesses were not continued below the caisson roof, the excavation had to stop at that level and the material in the narrow space between the ends of the caissons was loosened or removed down to the cutting edge by jet pipes 2 to 6 in. in diameter. Grout was then introduced and with the sand and broken stone already there formed a concrete filling between the caissons. Above the tops of the caissons the excavation between them was filled with concrete rammed in the ordinary way.

Plant for Foundation Work.—The lack of storage room for materials and plant, the necessity of avoiding all obstruction to pedestrians and vehicular traffic in the street, the requirements for safety and the urgency for great speed in construction developed special methods and plant for the execution of caisson foundation work which would not be justified under other conditions. Early in the progress of the work a very heavy platform with a capacity of 500 lb. or more per square foot is usually built at a height of 10 or 12 ft., above the curb extending over the sidewalk area and sometimes part way or even entirely across the street, a derrick is installed on it and it is used for loading, unloading and storing materials and for office room.



An Example of Complicated Underpinning.

In many cases as soon as the general excavation of the lot is completed a temporary wooden platform or deck with a capacity of from 500 to 1,000 lb. per square foot is built to cover most of the area of the lot at street level and is supported on piles or heavy framed falsework bents, located as much as possible to clear the positions of the caissons. Sometimes the sheeting to retain the sides of the excavation require so much transverse bracing that the sub-structure becomes very complicated and is framed into an extensive system of transverse and horizontal timbers of large dimensions. A tower traveler with four long derrick booms of large capacity is usually established on a wide-gauge track on the center line of the platform and moves from end to end of the lot, unloading the completed caissons from trucks and delivering them to the places where they are required on the site, through holes cut in the platform as necessary.

The platform serves as a causeway for teams moving continuously from entrance to exit for the storage of materials and for the location of some of the smaller plants. Elevated hopper-bottom storage bins are provided above the platform and the spoil excavated from the caissons is deposited in them as fast as hoisted, regardless of the dump wagons, which are rapidly loaded from them through chutes. The bins may have sufficient storage capacity to hold the material during all or part of the day and enable the wagons to remove it at night, when the street traffic is very much diminished. Concrete materials are chuted to storage under the platform, mixed by power machines at one or more points in the lot and delivered on industrial tracks laid in every direction in the bottom of the pit to serve the different piers where they are handled by fixed derricks or by those on the traveler, which together fully command the entire area of the lot.

Air compressors are installed in the most convenient places, often in the sidewalk vaults, and numerous small portable houses or sheds are located under and over the platform wherever most convenient for tool sheds, pipe cutters, carpenters, blacksmiths, sand hogs, storage, offices, etc. Pile drivers and pneumatic tools are installed as required and steam for the air compressors and the numerous hoisting engines is frequently purchased from a public power company, thus saving the expense and obstruction of a boiler installation. The substitution of electric motors for steam engines to operate the air compressors and hoisting engines has been tried, but so far little used. Elictric lights are installed and the work is carried on continuously with three shifts of men working under air pressure and one or two working under atmospheric pressure. Several hundred men are thus employed on the foundations of an ordinary office building, as many caissons are sunk simultaneously as can be provided for by the capacity of the compressor plant, and the work is carried on with great rapidity.

Needle-Beam Underpinning.—Notwithstanding the great care exercised in sinking pneumatic caissons, the excavation of quicksand at great depth under heavy pressure sometimes causes a movement in the adjacent soil and threatens undermining and settlement of foundations that are very near and at a higher level. Many times tall and heavy buildings adjacent to the new foundations have footings of poor construction or that are seated on the earth near the surface of the ground so that they are especially likely to be injured by a displacement of the soil. In such cases provisions to insure their absolute stability are the first preliminary for the new foundation work. In some cases the difficulty and danger of supporting or strengthening them are so great that they are torn down and rebuilt after the new foundations are completed. Ordinarily, however, they are reinforced if necessary and their adjacent foundations are first carried to rock or below the level which will be attained by the new foundations. This generally involves the removal of the old foundations and the temporary support of the superstructure while an excavation is made under it to the required depth and the new foundations constructed in it.

Formerly the common practice for underpinning buildings was to cut holes through the lower part of the walls, insert transverse needle beams in them, jack up their ends on temporary supports far enough apart to permit excavation and reconstruction between them, and finally to lower the old building to bearing on the new foundations and remove the needle-beams and their supports. This method involves great obstruction to the site of the new building and in the lower part of the old building and in the case of a very tall or heavy wall requires very large dimensions for the needle beams and often necessitates elaborate and extensive construction for the temporary supports under their ends. When the masonry is weak or poor it may not have sufficient strength to resist the concentrated stresses introduced and the operation becomes dangerous as well as difficult.

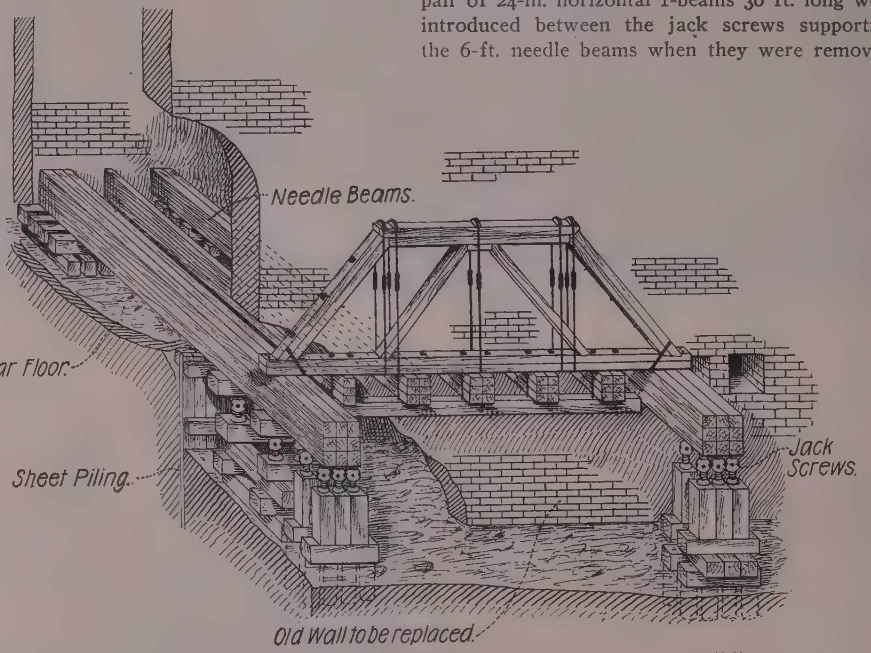
Usually the needle beams are made so long that when their ends are supported on longitudinal sills or cribbing they are beyond danger of undermining from the excavation sheeted down under the center of the wall for the new footing. If the loads are very great or the soil is very bad it is sometimes necessary to drive piles or sink piers under the ends of the needle beams, which is likely to be very difficult and expensive, especially in the interiors of the old buildings.

The 13-story wall of the Decker Building, New York, had an estimated load of 76,000 lb. per lineal foot and was underpinned by a new concrete footing carried down 6 to 12 ft. more to solid rock at a maximum depth of 30 ft. below curb to provide for the excavation of a tall new building adjacent. In this case pits were sheeted down on both sides of the wall to solid rock and in them concrete piers were built to carry the compound needle beams which consisted of double tiers of long 15-in. I-beams seated on numerous powerful jack screws. The loads were so great as to cause a noticeable deflection in the deep beams which, however, was reduced as much as possible by making the bearings of the upper tier of beams, on the top flanges of the lower tier, much closer together than the bearings of the lower tier on their jack screws.

In many cases heavily loaded columns and piers have to be underpinned when it is impossible to cut through them for the insertion of needle beams. Hollow horizontal grooves or recesses have been cut in their opposite faces near the bottom and I-beams placed in them taking bearing on regular needle beams on both sides and thus supporting the pier or column with free space under it between the needle beams.

In some cases it is difficult or impossible to find direct support for one end or other of the needle beams and they are sometimes suspended from transverse girders or are made to act as cantilevers carrying the wall on their short arm and having the long arm reactions provided for with counterweights or bracing. An example of such construction is afforded by a building at No. 44 Broadway, where the fulcrums were suspended and anchorage was secured by great weights of pigiron piled on a platform built across the extremities of the long arms of the girders.

The foundation work for the American Surety Company Building, New York, necessitated the underpinning of the very heavy 8-story walls of the adjacent Schermerhorn Building, which were temporarily supported on massive compound needle beams made with three tiers of 14 x 14-in. timber. The inner ends of these needles were supported on cribbing laid on the cellar floor in the interior of the Schermerhorn Building and in order to prevent obstruction in the lot of the Surety Building, the outer ends projected only 2 or 3 ft. beyond the face of the wall and were suspended from a massive timber truss close to the face of the wall.



Suspended Needlebeams for Underpinning the Schermerhorn Building.

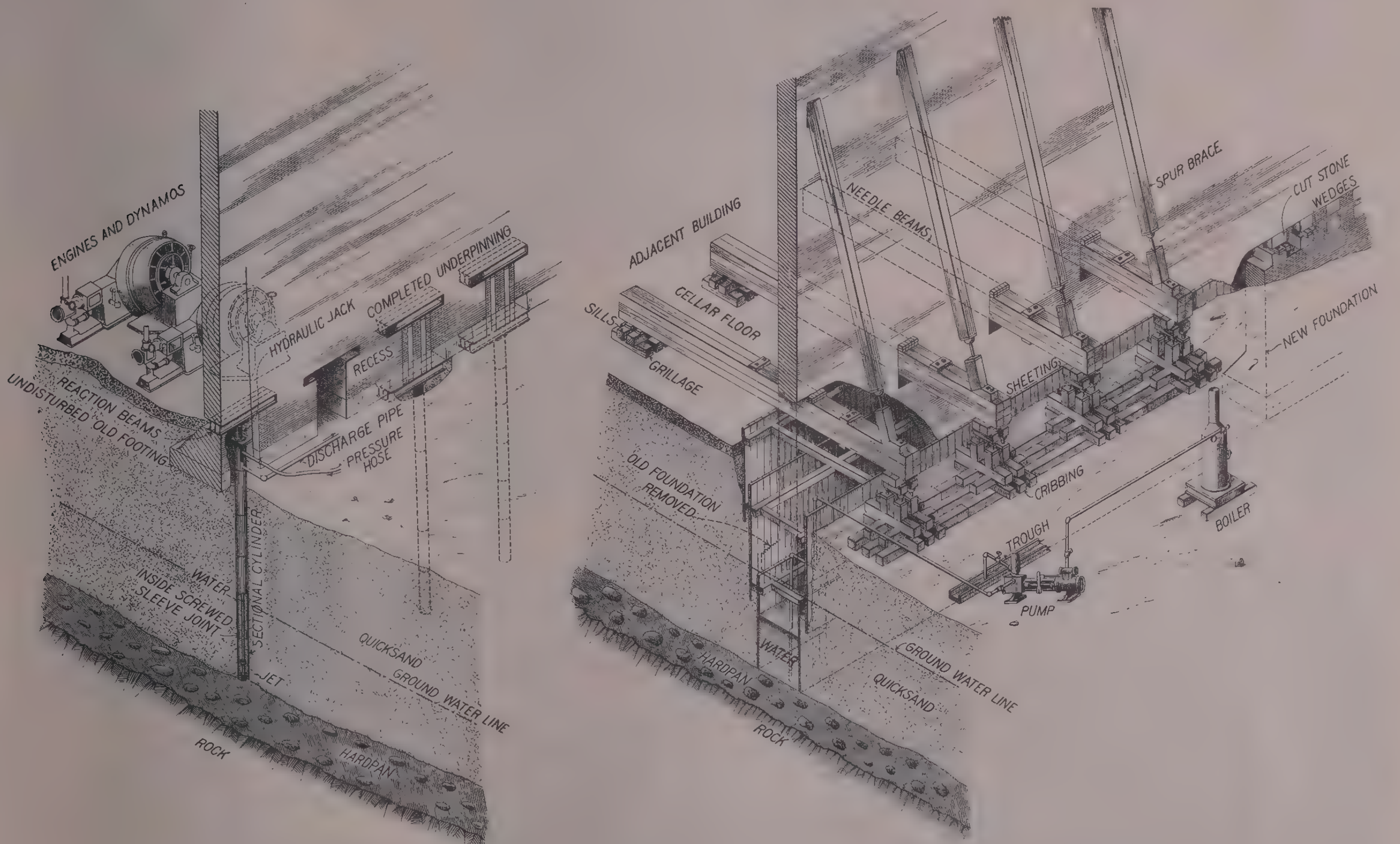
Special Underpinning Work.—The difficulty of underpinning a tall heavy wall with shallow foundations on deep soft ground, without obstructing operations in the adjacent lot and the number, magnitude, delicacy and costliness of the operations involved is illustrated by a building at 44 Exchange Place, New York, where a 6-story brick wall 93 ft. high above the street, 20 in. thick at the base and 35 ft. long, imposed an estimated load of about 12 tons per lineal foot with foundations seated near the surface, and a little above ground water level on a soil composed of sand, quicksand, clay and gravel to a depth of about 30 ft. with 10 ft. of clay and hardpan overlying the rock. It was thought that the construction of large pneumatic caisson foundations almost in contact with it for an adjacent new building would cause a flow in the quicksand that would greatly endanger the wall, and it became necessary to replace the old foundations with new ones carried down to the level of the new cellar floor without interfering with the sinking of the caissons.

The wall was braced with inclined shores and supported on 12 x 12-in. needle beams 6 ft. long and 3 or 4 ft. apart, set on 20-ton jack screws, carried by 12 x 12-in. longitudinal timbers close to the inner and outer faces of the wall. The longitudinal timbers were supported on needle girders about 18 ft. apart and 28 ft. long with both ends carried on crib work distributing their loads over a considerable area of the ground. Each needle girder was composed of twelve or sixteen 15-in. I-beams in double tiers with a clear span of 14 ft. for the lowest tier and steel bearing pieces between the two tiers which reduced the span of the upper tier to 10 ft. The needle beams were located in the spaces between the pneumatic caissons and their cribs were clear of the outer faces of the latter so that they did not interfere with sinking them. Careful levels were taken and the jack screws operated to raise the walls ⅛ in. and transfer its entire load to the needle beams, allowing the brickwork between them to be removed and replaced by a row of 5-ton jack screws seated on the lower part of the wall and give it additional support until a pair of 24-in. horizontal I-beams 30 ft. long were introduced between the jack screws supporting the 6-ft. needle beams when they were removed, the I-beams slipped over to their places and the 5-ton jacks immediately set on top of them and operated to transfer the weight of the walls to the 24-in. I-beams and release the short needle beams which with the 12 x 12-in. timbers were removed, allowing the caissons to be sunk between the needle girders. The 24-in. I-beams cantilevered about 6 ft. beyond the needle girders and carried a 72-ton wall load on the overhang without undue flexure.

After the caisson work was completed a trench was dug alongside and the new footing at the lower part of the wall built in it, the longitudinal beams and short needles replaced, the wall transferred to them, the 24-in. I-beams released and removed, the brickwork built a little higher, jack screws placed on it and screwed against the foot of the old brickwork, transferring the load to the new footing and releasing the needle beams and girders which were removed. The weight of the building settled the new foundations perceptibly and the jack screws were screwed up daily to compensate for it until the settlement ceased and the usual connections were made between the old and new brickwork and the jack screws removed.

A somewhat similar method of underpinning was pursued for the neighboring building at 51 Exchange Place, where the entire space in front of the wall was eventually occupied by the pneumatic caissons, involving a transfer of the weight of the wall from one set of supports to another. Temporary interior piers were also used because the space available for supporting the needle girders in the cellar of the building was only about 7 ft. wide so that cribbing or grillages on the cellar floor would have been in danger of undermining by the trenching for the new foundations.

The wall was 70 ft. high and 100 ft. long, with an estimated load of 16,000 lb. per lineal foot on the 2 x 4-ft. concrete footing only about 6 ft. below the curb. Short sections of 16-in. pipe coupled with inside screwed sleeves were sunk through the cellar floor by an hydraulic jet and very heavy suspended weights providing a reaction against which they were slowly jacked down. They were filled with concrete and capped to receive the I-beams, after which holes 3 ft. apart were cut through the foot of the wall and 12 x 12-in. short needle beams inserted in them and supported on jack screws carried by I-beams set close to both faces of the wall and bearing on the compound needle girders. The needle beams were replaced by jack screws and girders in the plane of the wall as explained in the previous description, and after a 30-ft. 500,000-lb. section of the wall was thus supported an equal adjacent section was treated in the same manner and so on, until the entire wall was carried on the needle girders.



Underpinning Heavy Walls by the Breuchaud Method, and by Needling, Trenching and Pumping.

The general excavation was not made until after the caissons were sunk, and as soon as the latter operation was completed it was found that additional caissons must be sunk in the spaces between the first caissons, occupied by the needle girders and the latter had to be shifted before the new footings for the wall could be built. Additional short needle beams were placed under the wall in the spaces between those already there, and were supported on jack screws resting on inside and outside longitudinal girders, each composed of two tiers of 14 x 14-in. timbers carried by transverse girders resting at one end on the longitudinal beams inside the building and at the other end on the concrete piers for the new building. The jack screws were operated to transfer the weight of the wall from the old needle beams to the new needle beams, thus releasing the former and the needle girders which, together with their cribbing, were removed, affording opportunity for the construction of the new intermediate caissons between the old ones. The needle beams were then replaced with wall girders as before and the obstructions being removed from the front of the wall, the intermediate caissons were sunk, the needle beams replaced, wall girders removed, trench excavated, new footings built, brickwork carried up to the girders, girders replaced by needles, weight of walls temporarily transferred to old footings to settle them, permanent connection made between old and new masonry and needle beams finally removed and holes filled. During the course of these operations the jack screws had to be adjusted almost daily to compensate for settlement of about 2½ in. and the wall had to be six times lifted and shifted from one support to another.

Underpinning with Cylinders.—Since the introduction of pneumatic caisson foundations for buildings, a new system of underpinning has been invented which has proved very successful and of great value and importance. It entirely eliminates needle beams, girders and wall bracing, avoids all obstruction of the adjacent lot or entrance of the building underpinned, does not require holes to be cut through the wall, does not diminish the support of the wall or require temporary bearings, dispenses entirely with trenching, sheeting and pumping, and provides permanent supports of any required strength carried through any soil to solid rock at any depth, and finally involves no operations except those of a very simple character, which are conducted almost entirely in the plane of the wall itself. This system is known as the Breuchaud process, and was first applied to the Stokes Building, New York, in 1896, since when it has been used without essential modification in a large number of very difficult and important cases.

The construction of the 18-story building for the Queens Insurance Co. involved the underpinning of an 11-story brick wall 140 ft. high with an 8-ft. concrete footing 12 ft. below the surface of the ground, and about 3 ft. above ground water level. The estimated load on the fine quicksand was about 11,250 lb. per square foot. I-shape recesses about 8 ft. high and 5 ft. wide, and 3 ft. deep were cut in the face of the wall near its foot about 7 ft. apart on centers and sets of horizontal reaction I-beams were placed in the upper part of each recess to afford bearings for 100-ton hydraulic jacks, with which short sections of 33-in. cast-iron pipes were forced down as the interior was softened and scoured out by a ¾-in. hydraulic jet. The successive sections of pipe were bolted together through inside flanges, and when it became necessary to excavate by hand below water level, horizontal diaphragms with air-tight doors were inserted between adjacent sections of the pipes forming an air-lock, through which a man entered and worked under pressure as in an ordinary pneumatic caisson. The cutting edge was sunk to hard pan, about 48 ft. below the curb, and penetrated it several feet to a bearing considered as satisfactory as rock, where the excavation was enlarged and horizontal steel plates placed under the cutting edge of the pipe to provide a bearing sufficient to reduce the pressure to 900 lb. per square inch. The pipes were filled with concrete, capped with heavy cast-iron blocks, on which transverse I-beams were seated to carry the old wall footings and vertical steel columns were wedged between the upper and lower I-beams, releasing the jacks, which were removed leaving the concrete filled pipes loaded about 350 tons each with the full weight of the wall. Seven cylinders were thus sunk rapidly and transferred the entire weight of the wall and its floor load to the deep foundations without interrupting other work, obstructing the site, or at any time impairing the stability or diminishing the support of the wall.

A large proportion of the important buildings which have since been underpinned in consequence of adjacent caisson sinking, and many others that have been underpinned on account of open excavations or other operations, have been done by this method, which has been repeated with slight modifications. In most cases the bearing plates have been found unnecessary under the bottoms of the tubes, and where the loads were comparatively light, pipes of smaller diameter have been used and were sunk entirely by water jets and jacking.

Several years later another wall of the same building was successfully underpinned by the same method, under difficult conditions, and which made the work one of great delicacy. This wall was adjacent to the Mutual Life Insurance Building, and was underpinned in advance of the construction of the very deep pneumatic caisson foundations for the latter. The wall, 170 ft. high and only 8 to 12 in. thick, was carried on four rectangular cast-iron columns built into its offsets about 5 ft. thick, and supported on a continuous concrete footing 6 ft. wide and 30 in. deep, and 18 ft. below street level. The brickwork was poor, and neither well bonded nor well connected to the columns, so that it was not considered safe to subject it to concentrated loads during underpinning, and the work was treated as specially hazardous. The face of the wall was strongly braced with inclined shores, and the lower part was enclosed between two continuous lines of plate girders set against the opposite faces and securely bolted through the wall columns. The brickwork was wedged to bearing on the top flanges of the girders, and was removed below them and pneumatic caisson cylinders were sunk under them and concreted, thus transferring the weight of the brickwork and the column loads through the permanent girders to the new piers.

GRADE CROSSINGS on the Pennsylvania Railroad between New York and Washington, and between Philadelphia and Pittsburg have been reduced by more than half since Jan. 1, 1902. On that date there were 994 grade crossings, whereas there are but 426 now, which are scattered over 571 miles of road, and are on unfrequented highways. The completion of the new Washington terminal marks the consummation of the plan to eliminate all grade crossings in important cities between New York and Washington. Between Philadelphia and Washington alone, 101 grade crossings have been removed.

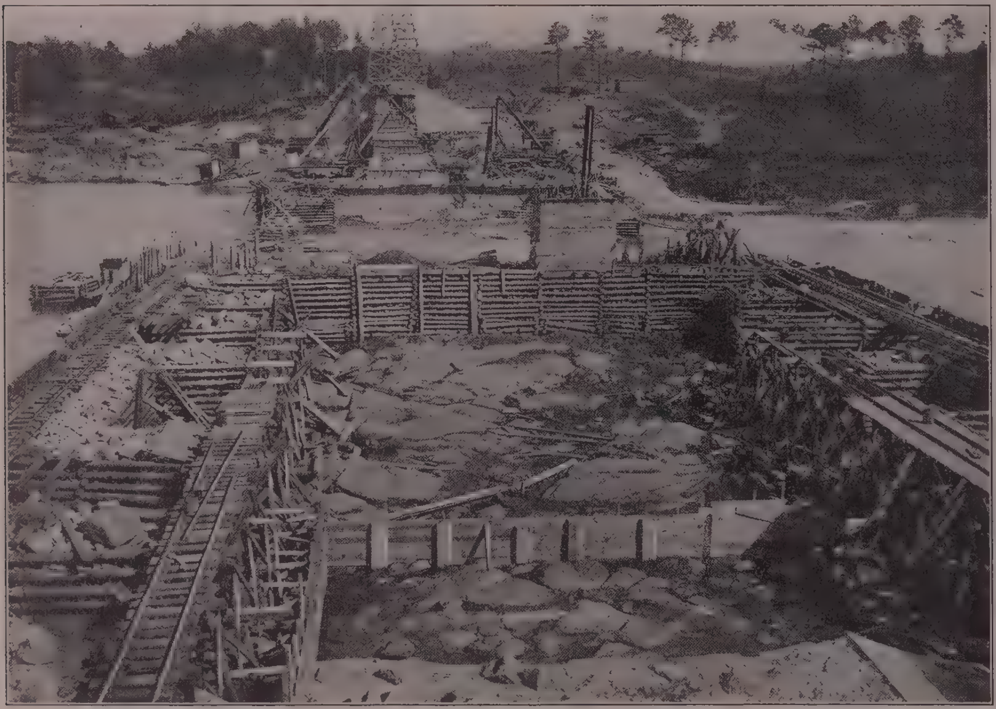
Construction Features of the Hydro-Electric Plant of the Rockingham Power Co.

By J. S. Viehe, Electrical Engineer.

The general topography near the Blewett's Falls on the Yadkin River and the fact that these are the last falls in the river determined the kind of development most feasible for the Rockingham Power Co. These falls, located about 9 miles northeast of the town of Rockingham, N. C., are themselves merely rapids or shoals, so that for these alone it was not necessary to make the development at this immediate site. At this place, however, there is high ground on each side of the river and apparently good foundation the entire width of the river from hill to hill. On the westerly side of the river the hill is of such a character as to at once suggest the form of development. It was noted that with comparatively little excavation the head water could be carried around this hill and the power house so located as to utilize several feet of head which occurs in a series of rapids below the location of the dam above noted. As the river is subject to extreme freshets which carry large quantities of drift the location chosen for the power house has the advantage of affording protection from these dangers.

With a head of 45 ft. the total power for delivery to customers as calculated from government reports is 30,000 horse-power. Of this power about one-half is available every day in the year, the other half being available about 90 per cent of the time. The company's plans call for a dam 1,468 ft. long between abutments, with retaining walls at each end and a core wall extending into the center of the hill on each side. The dam is to be approximately 50 ft. high, 10 ft. thick at the top and 60 ft. at the bottom. The upstream side is vertical, the downstream being formed in a long ogee. On the westerly side of the river a fishway is to be erected and so arranged as to enable fish to travel over the dam. It consists of a series of pools at different elevations extending from the water below the dam to that above. It is to be constructed entirely of concrete, the pools or pockets being separated by vertical walls of concrete with a small hole connecting adjacent pools.

Concrete Mixing Plant, Cable Towers and End of Dam.



Foundation Ready for Concrete in Mid-Stream Cofferdam, Rockingham Power Co.

The specifications call for the body of the dam to be of 1:3:6 concrete with about 30 per cent of large ballast stone, and a richer mixture for the exposed surfaces. The retaining walls, fishway, etc., are to be of this same mixture, but of course contain no ballast stone. The construction of this masonry is estimated to require a total of 90,000 cu. yd. of masonry, 33,000 cu. yd. of excavation and 57,000 cu. yd. of filling around the retaining walls.

The power house when completed will contain six 3,000-kw. generators, 4,000 volts 3 phase and 60 cycles, each directly connected to a line of four 51-in. McCormick turbines. As exciters there will be three 150-kw. 250-volt machines directly connected to independent wheels. The water cooled transformers will be 1,000 kw. each, three connected delta-delta and raising the voltage from 4,000 to 60,000 forming a group for each unit. The generators will be placed in a room 260 x 100 ft. and 40 ft. high, with their shafts extending outside to the water wheels located between the head gate wall and the generator room. The transformers, switchboard and all controlling apparatus will be located in a room 160 x 75 ft., 40 ft. high, adjoining the long side of the generator room, and arranged with three floors.

The building will be of brick and reinforced concrete, the whole resting on a substructure of concrete arches built up from the solid ledge. The head-gate wall or bulkhead through which the 15-ft. feeders for the wheels are carried is of concrete and ballast stone and located directly across the end of the forebay, 40 ft. from the power house wall. The total masonry for this portion of the work is estimated to be 27,000 cu. yd. of concrete and the excavation here, in the forebay and tailrace will be approximately 400,000 cu. yd.

The first work consisted in building shacks for the men, a boarding house, commissary and a commodious dwelling for the engineers. A railroad was then built from the site to the main line of the Seaboard Air Line, a distance of about four miles for delivering all materials to the work.

One of the interesting features of this development is the fact that great abundance of good gravel near by eliminate the necessity of putting up a rock crushing plant. It will be interesting to give briefly the method which is used to secure both sand and gravel from a pit which has up to the present time supplied the need for these materials. This pit, located on the railroad at a point about six miles from the site, has a vein of gravel which varies from 6 to 12 ft. in thickness, and about 20 acres have now been opened up. The surface of the gravel was first scraped off to get rid of roots and loam, thus leaving the sand and gravel in a very clean condition. By means of teams and scrapers this material is hauled up to a hopper from which it is loaded into 6-yard dump cars and then hauled by a dinkey engine over a narrow-gauge track to the hydraulic washing plant. The cars are dumped into the top of a sluice box 3 ft. wide, 1 ft. deep and approximately 250 ft. long inclined at an angle of about 30 deg. with the horizontal, a 5-in. stream of water entering the sluice at the same time and washing down the material. The bottom of this sluice for a distance of about 20 ft. at the lower end is a screen of ½-in. mesh with a hopper underneath. As the sand and gravel come to this screen the sand and water pass through and into the hopper while the gravel passes over and into standard railway cars. The sand hopper fills up with water and sand, the former overflowing and the latter settling to the bottom to be drawn off by a valve into standard cars. As the cars are loaded they are run down out of the way by gravity and others run in to be loaded. The company's engine hauls the cars to the work and keeps a supply of sand and gravel on hand.

Hydraulic Dredge, Rockingham Power Co.

Condition of Work on Dam on October 29, 1907.

One of the cuts shows a trestle which has been built by the company for constuction purposes and forms an important part in the general method of making concrete. This trestle is approximately 60 ft. high and 300 ft. long. Cars loaded with sand and gravel are run out on this trestle and dumped into bins beneath. At the entrance to the trestle is located the cement shed with a capacity of 6,000 bbl. Underneath the bins a narrow-gauge track has been laid in the form of a loop so that cars can be run under and get the three ingredients for concrete. The cement is received at the end of the loop through an automatic measuring device and a chute extending to the top of the trestle. These loaded cars can then be carried to two mixers; one a cube mixer with a capacity of one yard located near the top of the elevator shown to the right of the trestle and the other a Smith mixer with a similar capacity located just above the level of the ground and to the right of the elevator shaft. For the cube mixer the cars are pushed by hand under the elevator shaft, lifted to the top and then dumped into the mixer, the water being supplied after dumping, but before mixing. For the Smith mixer the cars are hauled up a slight incline by cable and then dumped into the mixer, the water entering during the process of mixing.

View of Section of Dam during Construction, Rockingham Power Co.

There are two independent methods of delivering concrete to the work, first by cable and second by cars pushed by hand along tracks laid on the cofferdams. The cableways are of 2½-in. steel cable stretched between towers 100 ft. high, the span from tower to tower across the river being 1,840 ft. and the two cables about 25 ft. apart. The cofferdams are made up of cribs constructed in the usual way by spiking together rough timbers and then filling with rock. Ordinarily these cribs are 12 ft. square, but at intervals cribs 12 x 30 ft. are put in to strengthen the whole. As the work proceeds, temporary wasteways 12 ft. square are left near the bottom of the dam about 75 ft. apart and at such places the longer cribs are used on each side of the waterways. The dam is built in sections of about 300 ft., each section being completely surrounded by cribs until a sufficient height of masonry is reached. The sheathing on the outside consists of 4-in. plank grooved on each edge for splines which are driven in after the planks are driven into the mud. For removing the water from a section a 6-in. centrifugal pump and an Emerson pump are used when the cofferdam is flooded, but after the bulk of the water has been removed the Emerson pump is sufficient to keep the water down.

The method of placing these cribs gives sufficient room on top by adding a small amount of trestle work for two parallel tracks on each side of the dam. On each pair of tracks there is operated a traveling derrick which is used to place large building stone, or to lift tubs of concrete from cars and lower them to the work. The ballast stone is obtained from a quarry located a short distance above the dam on the power house side of the river and hauled by mules to the cofferdams, then pushed by hand along the tracks on these cofferdams to the desired place.

After pumping the water out of the cofferdam, the next work consists in preparing the foundation. The loose earth and stone are shoveled into skips, hoisted by cables and deposited behind the wing walls, or taken out by the traveling derricks on the downstream side and deposited in the river. Where the ledge was perfectly solid no trenches were dug in it, or any blasting done, but in places where the foundation seemed porous but had good bearing qualities, a trench was made near the upstream side to prevent seepage and near the downstream side to prevent undercutting. In one section for a distance of about 300 ft. it was necessary to make the upstream trench about 6 ft. wide, with an average depth of about 18 ft. below the river bed. At this depth the solid ledge was not found, but as the foundation seemed much better it was thought that this 18-ft. wall would eliminate all danger of seepage and the laying of concrete was begun.

The concrete was delivered by cable and rail, as already noted, and then spread by men with shovels. No tamping was done, the concrete being placed sufficiently wet to keep water standing on top all the time. The large ballast stone, varying in size from 1 cu. ft. to 2 cu. yd., was placed by the derrick located on the upstream side of the dam in quantities sufficient to make solid rock form about 30 per cent. of the mass.

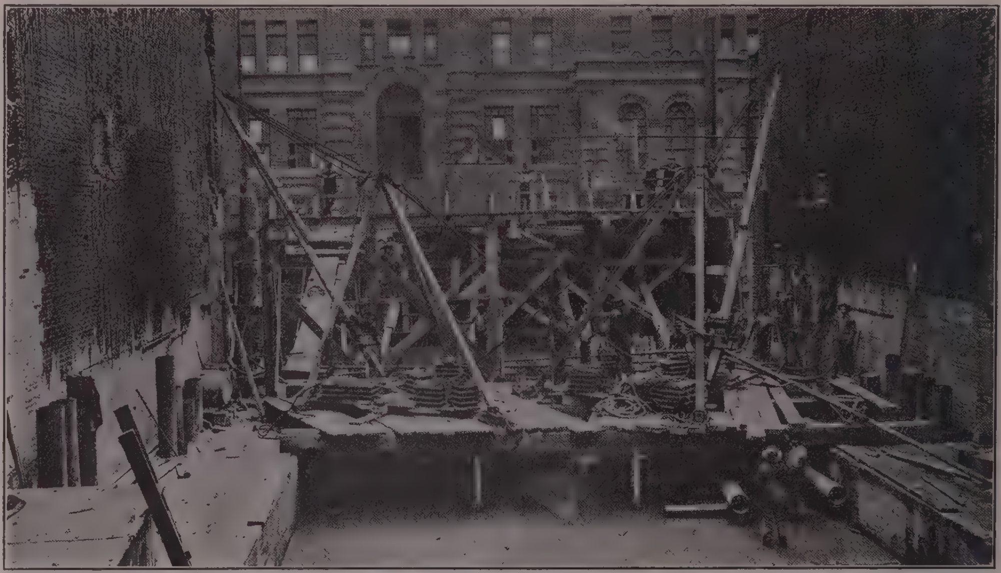
The forms for the concrete consist of boards nailed to cross pieces cut to suit the lines of the dam. These forms were then wired to large rock in the dam, or to concrete that had hardened. When it was desired to remove the forms, the wires were unfastened from the forms and then clipped off close to the concrete. In building a section of the dam, recesses were left in the end to form a bond when the next section was put on. The temporary wasteways will be left in the dam until it is desired to raise the water in the forebay, that is, until all other work is completed. The method of filling these wasteways as originally planned is to put down timber gates on the upstream side and then fill in with concrete from the lower side, the final grouting being done through terra cotta pipes extending to the top of the dam and put in place during construction. An improvement over this method is the use of a 3-ft. square chimney extending from the wasteway to the curved surface of the dam, and this method has been adopted for all future work.

The work at the power house is carried on by cable and derrick, much along the same methods as those used in building the dam. There is one cable strung across the power house area on traveling towers arranged to move laterally, thus covering the entire area. The side walls have been put in by derrick. These walls as well as the head-gate wall have been nearly completed. The excavation for the power house is well under way, the material being removed by scrapers, an occasional boulder only requiring blasting.

One very interesting feature of the work is the method of excavating the tailrace. The quantity of material, consisting largely of clay with an occasional boulder, is approximately 300,000 cu. yd. This material is being removed by an hydraulic dredge. The dredge consists of a barge 60 x 150 ft., on which are mounted a centrifugal pump with engine direct connected, boilers and steam winches. The centrifugal pump, which is at the bow and has a 20-in. discharge pipe, runs at a speed of 120 r.p.m. Just in front of this pump is a large swinging arm consisting of a shaft mounted in bearings resting on the suction pipe. This arm has a vertical motion only, being fastened to the corners of the boat by stays. At the end of the shaft is located the cutter, having four knives about 4 ft. long and revolving in a circle with 5-ft. diameter. These knives are inclined slightly toward the shaft at their front end and surround the end of the suction pipe to break up the material and throw it near the end of the pipe. At the boat end of the swinging arm and mounted on it, is the engine for driving the cutter, the connection between the suction pipe and the pump being made with a large, corrugated rubber hose. The side swing of the boat is secured by cables on each side leading to dead men in the ground and taken in or let out by the winches. The forward motion during operation is obtained by the use of two sharpened timbers called spuds located abreast of the stern and let down alternately as the boat swings back and forth. The discharge pipe is carried through the boat, out the stern and then on floats on pontoons to the bank and then to the point where the material is to be deposited. The maximum lift is 14 ft.

In the operation of this dredge considerable difficulty has been experienced in the handling of blue, or pipe clay as it is known in this locality. This clay is very sticky and in passing through the pump sometimes clogs it so that it is necessary to open up the pump and clean out the material, and then pump only water for 15 or 20 min. to wash out the pipe. It also causes the cutter to undermine the bank so far that when it finally falls, the earth falls behind the suction end of the pipe requiring the dredge to move back and clean up this material.

In order to avoid the delay due to these troubles and to generally facilitate the work, a method of blasting has been resorted to. Light charges of dynamite are put down just ahead of the dredge to loosen up the earth and make it cave in rapidly, and this method has proven very efficient. A great deal of the material passes through the pump and is discharged in lumps from 12 to 15 in. in diameter. It is not unusual to hear a rock of this size bumping along through the pipe. One of the cuts indicates the dredge in position. The dredging is being carried out by the Sanford Brooks Co., of Baltimore.



Movable Derrick Platform over Pit, New York Edison Substation.

The entire work in connection with the construction of the dam and power house is under the general supervision of the Federal Construction Co., of Boston, which has sublet the contract to the W. R. Bonsal & Co., of Hamlet, N. C. All plans, methods of procedure, and general progress of the work are under the direct attention of Mr. W. A. Leland, resident manager of the Federal Construction Co. at Rockingham. The labor employed has consisted almost entirely of negroes and their work has been very satisfactory. Of course, white foremen without exception are employed, and as all of these are men of experience in the handling of negro labor it is thought that the inefficiency which is sometimes claimed has been obviated.

Although very little work has been done on the construction of the transmission line, the design of this may be of interest. Although the territory to be served by this power is located where cypress poles are very abundant and can be obtained very cheaply, after considerable discussion it was decided to use steel towers on account of greater reliability, greater life and small extra cost. The tower to be used was designed by the Aermotor Co., of Chicago, with the aid of the company's engineers. It is a square tower with 12-ft. base, 55 ft. high and weighs approximately 2,000 lb. The three transmission cables of No. 1 copper are arranged in a 7-ft. equilateral triangle with apex downward. Above the transmission wires is located a ⅜-in. galvanized steel ground wire. Telephone wires of No. 6 steel will be strung 6 ft. below the transmission wires. This telephone line will connect together all substations and the power house. As considerable trouble is sometimes encountered with a telephone line running close to a 60,000-volt power line, a special transforming device is to be used at each station to keep high voltage currents from reaching the local telephone circuit. The towers will be spaced 600 ft. apart in level country, but in rolling country spans as long as 900 ft. will be used in passing from hill to hill.

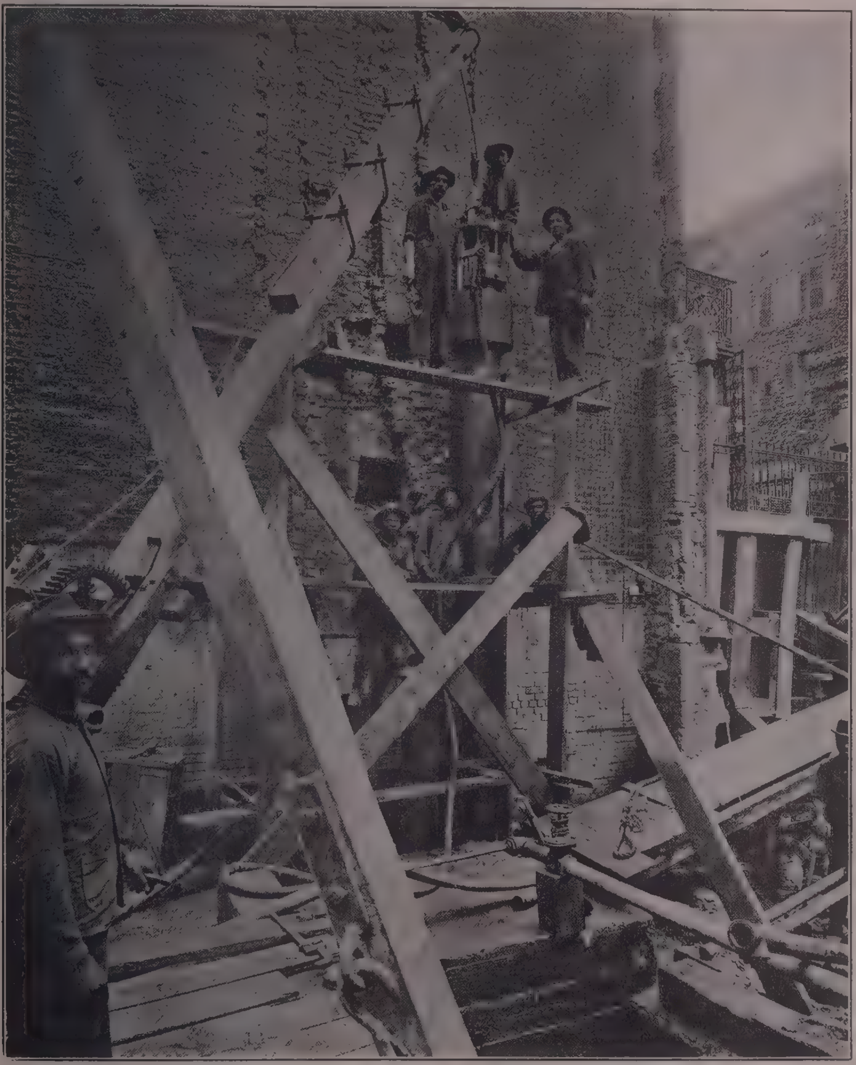
None of these towers has as yet been erected, but anchor pieces for about 30 miles of line have been installed. The leg of these anchor pieces is of 3 x 3 x ¼-in. galvanized angle iron, about 6 ft. long, with two cross pieces about 2 ft. long at the bottom. These pieces are set about 5 ft. in the ground by means of a templet and carefully leveled and then tamped. It is the intention to set the anchors and allow the ground to settle before the towers are erected. The building of the transmission line is being done by the Federal Construction Co.

Lockwood, Greene & Co., consulting engineers, of Boston, are furnishing complete plans and specifications for the entire undertaking, including transmission line, substations, power house and dam.

Low Operating Costs have been attained in the new gas-fired power plant at Jayenn, W. Va., of the Fairmont & Clarksburg Traction Co. The plant equipment consists of six 417-hp. Aultman-Taylor water-tube boilers equipped with superheaters which supply steam at 175 lb. pressure to two 500-kw. and two 1,000-kw. Curtis turbo-generators. The boilers are fired with natural gas of a calorific value of 1,050 B. t. u. per cubic foot, which is obtained at a cost of 5 cents per 1,000 cu. ft., and the station records up to Dec. 1 show that an average of but 29.97 cu. ft. were consumed per kilowatt-hour. The operating figures for the month of November, 1907, are as follows: Cost of fuel, $1,597; labor, $543; oil and waste, $13; repairs, $28; total, $2,181; output, 1,030,200 kilowatt-hours; cost per kilowatt-hour, $0.002117. Practically the same power costs were obtained for the months of October and September.

Special Foundations for a New Edison Sub-Station.

The New York Edison Company's sub-station at 16th Street, New York, is a steel frame building 50 ft. wide and 92 ft. deep with a single story about 80 ft. high. It is located on soft wet ground and as it contains heavy, high speed machinery, with foundations carried down below the level of the footings of the adjacent buildings, care was taken to separate the foundations for the rotary converters from those of the steel columns, and to build them without incurring danger of settlement or undermining of the foundations of the adjacent buildings. The walls of the adjacent buildings were weakened by large recesses for fireplaces and flues; on this account, special care was taken to avoid subjecting them to unnecessary stress, shock or vibration. The use of ordinary or numerous piles for the new foundations alongside was seen to be impracticable.



Driving Pile Tube with Special Pneumatic Hammer.

These foundations were therefore designed with special piles, intended to have such strength and durability that a few of them would suffice for each footing, and to be adapted for driving with little disturbance to the surrounding soil. Heavy steel tubes filled with concrete were believed to meet these requirements and were used for the foundations on three sides of the building and for two interior piers. The remaining eight foundations for interior columns were of the ordinary steel beam grillage type with concrete footings on the surface of the sand.

The isolation of the foundations for the rotary converters was accomplished by building them in a 35 x 70-ft. pit about 7 ft. deep with concrete sides and bottom. The pit was filled with a monolithic mass of cinder concrete 6 ft. deep, which acts as a cushion for the masses of concrete upon which the machines are seated at cellar floor level. A continuous sheet of lead about ⅛ in. thick, having soldered joints is interposed between the machines and the concrete. The side walls are also isolated from the adjacent buildings by 2-in. air spaces and all contacts or bearings between them and the foundations are avoided.

The foundations for the side wall columns are long and narrow, so as to bring their center lines about 20 in. from the face of the adjacent wall and distribute the loads over single rows of piles. The two interior pile foundations are of similar character and their piles were driven through the pit for the rotary converters before it was filled with the cinder concrete.

The foundations for the wall columns each have two, three, or four piles, 2 ft. apart on centers with their tops enclosed in a concrete footing 21 in. thick in which are embedded three or four lines of 15-in. grillage beams, about 4 to 8 ft. long, with their top flanges at cellar floor level, 7 ft. 6 in. below curb line. The I-beams are bolted together in the usual manner with cast-iron separators over the pile centers. The bases of the steel columns are set directly on the top flanges of the beams.

Each pile is made with a cylindrical steel shell, ⅜ in. thick and 12 in. internal diameter, filled with 1:2:3 concrete made with Trowel brand Portland cement and ½-in. broken stone. The piles are proportioned for loads of 86 to 140 tons. Such pile tubes as are filled with concrete only have an estimated capacity of 72 tons each. For loads greater than this, the capacity is increased by reinforcing the concrete with full-length vertical steel bars 2 in. in diameter which, for this work, were used in sets of two, three, five and seven per pile. The tops of the piles project 6 in. into the concrete footing and are covered with cast-iron caps.

After the general excavation was completed, the large central pit was excavated and its concrete side-walls built, before the construction of the pile foundations was commenced. The pit was bridged with 12 x 12-in. transverse timbers 40 ft. long shored up by movable vertical posts and covered with planks, thus forming a working platform, on which were seated two ordinary jinniwink derricks, such as are generally used for the erection of light structural steel work. The frameworks of the jinniwinks, not having any available anchorage to steel girders, which are generally utilized in buildings, were ballasted with the cast-iron caps for the piles, and were lashed to the framework of the platform and guyed by hand tackles. The derrick booms about 40 ft. long had a nominal capacity of about 2 tons. The topping lifts were operated by hand tackles and the wire rope hoisting tackles were operated by 2-hp. air-motor winches which were bolted to the booms. A horizontal locomotive boiler, and an Ingersoll-Sargent air compressor were installed in the street just beyond the sidewalk bridge. A Davidson plunger pump with 5-in. suction was installed in the basement. A 4-in. air pipe and a 2-in. water pressure pipe were run from end to end of the lot on each side with valved outlets about 20 ft. apart. A special, medium size, air hammer weighing, 2,200 lb., was suspended from each of the derrick booms and with them the wall piles were driven successively from one end of the lot to the other.

The steel tubes for the pile shells were received in sections up to 21 ft. long and were driven by the combined effects of the hammer and a water jet, at from 40 to 60 lb. pressure delivered through a 1¾-in. nozzle, inside the pipe.

The hammer made about one-hundred and fifty 15-in. strokes per minute, and was provided with a sleeve or cap engaging the upper end of the pile tube and securing it thereto, so that it was operated without ways or guides, and imposed its full weight upon the pile. The vertical piston was hollow, affording a hole of sufficient diameter to receive the jet pipe and permit it to be moved up and down while the hammer was at work.

The piles were thus driven by the combined impact and scour so rapidly that as many as 11 were driven in a single day to bearing on solid rock at depths averaging about 22 ft. below the basement floor. They penetrated an upper layer of filled soil, 20 in. of peat, a varying depth of sand and silt, and about 2 ft. of hardpan overlying the rock. The hydraulic jet was delivered through a hollow chisel-like nozzle, which was churned up and down to cut the hardpan. After the piles were sunk to the required depth and the earth and sand removed they were concreted and the steel shells and reinforcement bars, if any, were cut off to the required level by a special machine designed by Mr. A. B. Clark.

A large amount of water was requisite for jetting down the pile tubes and a considerable expense which would have been involved by purchasing it from the city and wasting it, was obviated by the expedient of using the water over and over again and storing it in the large pit already described which had previously been excavated and walled to receive the foundation cushion of cinder concrete. This pit was allowed to remain partly full of water and not only served as a sump for general drainage but received the discharge from the sinking machines described above.

Thirty-eight piles in all were sunk and the work was prosecuted vigorously by an average force of 25 men. During its progress and since its completion no settlements, cracks or other injuries have been noted in the adjacent walls and since the installation of the machinery no vibrations whatever have been observed in the neighboring buildings.

The work was designed and executed under the direction of the Engineering Department of the New York Edison Co., The P. J. Carlin Construction Company was the general contractor. Levering & Garrigues fabricated and erected the structural steel work and the foundations here described were constructed by Clark & Co.

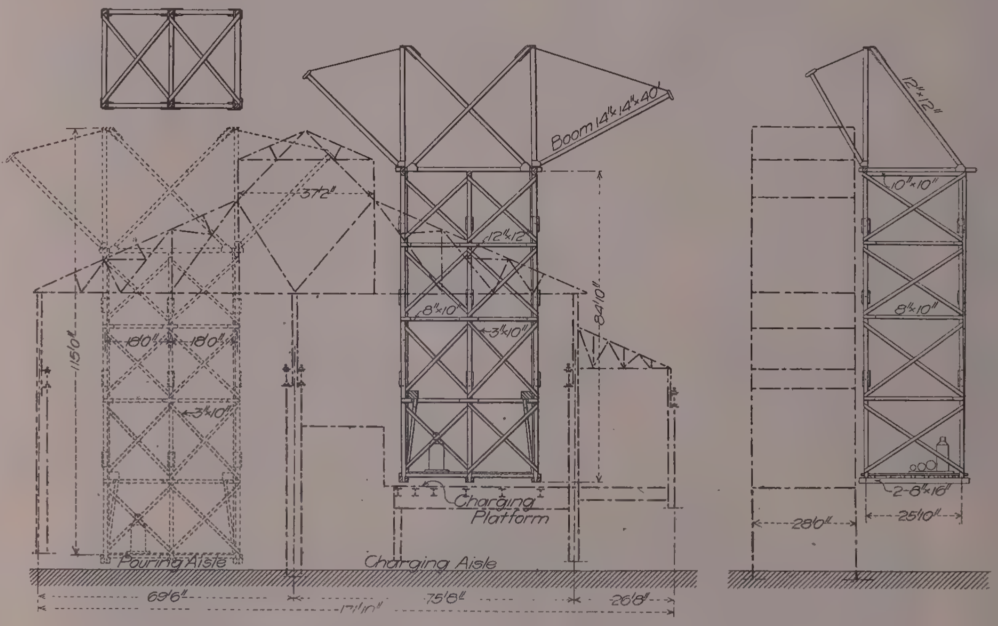
Sewage Disposal at Manchester.

Sewage disposal at Manchester, England, is now conducted as follows, according to Supt. D. E. McComb, of the Washington Sewer Department: The sewage first passes through a screening house, where mechanical appliances remove floating substances, sand and grit; thence it is led into a sedimentation tank, thence to twelve septic tanks, thence to the filter beds, the effluent being discharged into the Mersey Canal. Ordinarily one sedimentation tank is in use; during storms the sewage passes through four tanks. The excess sewage during storms is diverted to the storm water filter beds. The sedimentation tanks are each 300 ft. long, 100 ft. wide and 6 ft. deep and have concrete floors. The septic tanks have the same dimensions, with capacity equal to half the daily flow of sewage. There are 92 filter beds, each covering one-half acre, their nominal aggregate capacity being 63,000,000 gal. in 24 hours. The depth of bed is 3 ft. 4 in. Underdrains are formed of radial channels in the concrete bottoms covered with perforated slabs, the top of which are flush with the concrete floor. The spaces between underdrains is formed in ridges. The material of the bed is furnace clinker between ¼ and 2½ in., the coarsest portions of which are used to cover the subdrains and concrete bottom. Ordinarily the beds are filled and emptied four times each day, with full period of two hours for each cycle. The storm water beds are used to treat excess sewage during storms. There are 32 beds, covering 26 acres, the material being clinkers 2 ft. 6 in. deep. These beds are filled to a depth of 6 in. above the top surface of the clinker when discharge commences. After the storm the water remaining in the bed is drawn off by opening the drainage sluice gates. The purification effected is not wholly satisfactory, and it is proposed to install beds for secondary treatment upon the basis of double the rate of operation of the primary beds. Upon the occasion of Mr. McComb's visit one of the beds was being renewed after 4½ years' use. It appeared to be badly clogged with broken-down clinker and sludge. Additional underdrains were being laid, the impression being that sufficient underdrains were not provided for the beds when originally constructed. An experimental second contact bed has been operated for 3½ years with good results attained. It is claimed that the flocculent matter in suspension in the effluent from the primary beds is fully eliminated. The gaseous odor from the septic tanks was disagreeably noticeable on the public road about ½ mile from the works. The operation of controlling gates from a central station proved unsatisfactory and was abandoned.

An Experimental Briquetting Plant for peat has been in operation at Lynnfield, Mass., for some time, which is producing such satisfactory fuel that plans have been prepared for the erection of apparatus having a capacity of 50 to 75 tons per day. The process used was devised by Mr. E. Curtis McKenney, of Saugus, and the product is stated to be a very hard briquette which can be handled without much breaking and burns to a light ash, without any clinker and without much smoke.

Erecting an Open Hearth Furnace Building.

The 172½ x 448-ft. steel building for the new open hearth furnaces of the Pennsylvania Steel Co., at Steelton, Pa., is about 117 ft. in extreme height and contains 5,610,000 lb. of structural steel. The framework has four rows of vertical columns 68 ft. 6 in., 75 ft. 8 in., and 26 ft. 8 in. apart on centers transversely and 28 ft. apart longitudinally. In each bent the two roof trusses over the main aisle carry on their top chords a 37-ft. monitor truss and the narrow side aisle roof is carried by a lean-to truss. There are two lines of longitudinal runway girders in each aisle for the full span traveling cranes of large capacity and in the charging aisle there is a very heavy steel floor 22 ft. above the main floor, which is proportioned for a load of 400 lb. per square foot and weighs 2,325,000 lb. The center columns are of very massive construction weighing 24,000 lb. each and like the riveted roof trusses were all delivered complete from the adjacent bridge shops to the site of the building. The structural details were illustrated and described in The Engineering Record of Feb. 29.



Successive Positions of Traveler in Erecting Open Hearth Furnace Building.

The steel work was erected by a tall wooden traveler moving back and forth longitudinally and making several trips through each of the main aisles of the building. It consisted of a 26 x 36-ft. rectangular tower nearly 90 ft. high mounted on six double flange wheels on three lines of rails 18 ft. apart on centers. The 14 x 14-in. x 32-ft. masts of two stiff-leg derricks with 14 x 14-in. x 40-ft. booms were seated on the tops of the two forward corner posts. The six vertical posts were each made with single 10 x 10-in. timbers in four lengths from 14 to 28 ft. long spliced with butt joints scabbed; on each face there were five lines of horizontal struts chiefly made with 8 x 10-in pieces and the panels between them were X-braced with 3 x 10-in. planks. The longitudinal sills were pairs of 8 x 16-in. timbers engaging the feet of the vertical posts and receiving the flange wheels. There was horizontal X-bracing of 3 x 10-in. planks at the top and bottom of the tower and the derrick sills and stiff-legs were made with 12 x 12-in. timber. The traveler contained about 21,000 ft. of yellow pine timber and the derrick contained about 6,000 ft.

The traveler was equipped with a hoisting engine and boiler seated on a platform supported by the bottom sill just above which, on opposite sides of the tower there were 10-ton counterweights of rails. The estimated weight of the traveler and rigging, fully equipped, was about 140,000 lb., the maximum loads handled were 24,000 lb. for the lower sections of the heaviest center columns, 14,700 lb. for the outside columns, 11,400 lb. for the runway girders and 6,600 lb. for the trusses over the charging aisle. The maximum uplift provided for by the counterweights of rails was 10,500 lb., for a 21,000-lb. load with a 13-ft. radius transverse to the traveler and 16,700 lb. for a 14,500-lb. boom load with a radius of 30 ft. longitudinal to the traveler. The engine and boiler were located at the rear of the traveler on the side farthest from the center columns, thus bringing the center of gravity eccentric from the center of the tower and only 6½ ft. from the rear posts and securing stability for the traveler without anchorage.

The traveler track was first laid on the surface of the ground concentric with the pouring aisle and erection was commenced at the east end of the building, the traveler moving backwards, and as it receded erecting the lower sections of the two south rows of columns. From the west end of the building the traveler returned erecting the upper sections of the columns, crane girders, and longitudinal struts, and in the third operation moved a second time from east to west, erected the roof trusses and completed assembling all members of the successive panels.

As there was not clearance for the traveler to pass between the end of the furnace building and an adjacent building it omitted to erect the last column at the east end of the center row and the corresponding roof truss on the second and third trips, and at the end of the third trip, in its final position in the end panel of the building erected the first panel of the charging floor in the other main aisle and was then carefully guyed, jacked up on cribbing 22 ft. high, and moved transversely about 80 ft. to a track laid on the charging floor close to the north side of the building. While in this position it completed the erection of the last bent and the last panel in the east end of the pouring aisle and then moved forward to the east end of the building, erecting in advance only a sufficient width of the charging floor to carry its temporary track.

Care was taken to fill two-thirds of all field rivet holes in the column and floor beam connections with bolts or drift pins, to give abundant security for erection stresses. As each floor beam was erected in advance of the traveler, care was also taken to connect the stringers for the traveler tracks to both the front and rear sides of the web, thus completing their connection, and in order to accomplish this the forward ends of the front stringers were temporarily supported on a falsework bent swung to position by the derrick booms and removed after the stringers had been connected to the next floor beam.

From the east end of the building the traveler made its final trip back to the west end, erecting as it went the roof trusses over the charging aisle, the monitor roof trusses, the lean-to roof trusses over the narrow aisle, and completing the erection of the longitudinal members and diagonals in every panel. Special crane girders weighing 37,500 lb. each were not handled by the traveler but were hoisted to position by tackles suspended from the adjacent roof trusses previously erected.

The work was done under the direction of Mr. E. C. Felton, president, and Mr. J. V. W. Reynders, vice-president. The steel superstructure was designed, manufactured and erected by the Bridge & Construction Department, Mr. Thomas Earle, superintendent, Mr. F. C. Kunz, chief engineer and Mr. F. W. Cohen, engineer of erection.

Traveler on Charging Floor and Part of Framework Erected, Open Hearth Furnace Building.

Erecting Columns in Occupied Offices.

The construction of the Singer Building at Liberty street and Broadway, New York, involves two large new wings and the extension of the old Singer Building, which forms part of the new Singer Building from a height of 11 to 14 stories. As the old curved mansard roof was two stories in height, it had to be completely removed in order to allow the street walls to be carried up vertical to the 12th floor, consequently the 7th, 8th and 9th story walls on the street sides were entirely taken down and were rebuilt from the 7th floor upwards.

A careful investigation of the columns and footings showed that most of the old cast-iron columns were strong enough to carry both the old building and its extension, the latter being made with riveted columns and the usual steel cage construction. There were, however, two pairs of old cast-iron columns about 22 ft. apart on centers which, although entirely competent to carry their original loads, were not strong enough for the three additional stories, consequently two new steel columns were placed midway between them, each supporting at the center point in the 9th floor a triple-web box girder about 24 ft. long over all.

These girders are symmetrically balanced cantilevers, overhanging their single supports 12 ft. on each side, and supporting at their center point and their extremities three 9-story columns, which together bring a load of about 423 tons to the supporting column, which is made with a rectangular closed cross section built up of two 15-in. 55-lb. channels with 16 x 1¼-in. cover plates on both flanges. The girders are true cantilevers, for, although they are connected to the tops of the old cast-iron columns in the 8th story on the lines of the new steel columns above, the connections are made with bolts through slotted holes in the vertical flanges of the connection angles, which merely give lateral stability to the girder but cannot transmit vertical loads.

A large proportion of the cellar floor area was covered by the I-beam grillages which form the footing for the columns in the original building. Some space was, however, left vacant underneath the long span girders which connected the pairs of cast-iron columns reinforced by the new one, and here the old concrete floor was removed and a shallow excavation was made to the undisturbed sand on which were built new I-beam grillages enclosed in the usual manner in solid concrete and occupying nearly all of the space previously vacant. This part of the work was done without restrictions, as the cellar was not tenanted, but all of the stories above were occupied and it was necessary to carry the two columns through them and make connections to the existing floor girders without inconveniencing the tenants or interrupting business. This problem would have been sufficiently difficult under any conditions, but was made much more so by the fact that the first floor was occupied by a bank, and one column passed directly through the center of the railing separating the cashier's desk from the public, and another passed within an inch or two of the 50-ton vault.

The contractor's men commenced operations one evening after the close of the bank by constructing on the center lines of the columns two small enclosures, each of them not more than 6 ft. square, which were accurately sided from floor to ceiling with matched boards and covered with building paper to exclude the dust. Access to the interior was provided by doors, the ceiling was removed inside the enclosure and the old floor girder, which consisted of a pair of 24-in. 120-lb. I-beams, was supported on two sets of vertical shores about 4 ft. apart in the clear. The first floor girders, which also consisted of a pair of 24-in. 120-lb. I-beams, were supported by a pair of vertical shores about 4 ft. apart in the clear, which were set up in the cellar. A hole was cut through the first floor inside the enclosure, giving access to the girders and allowing a section about 20 in. long to be cut out of the middle of the girders with hack saws. These were 2 ft. long, provided with special frames, and were operated by two men. One man working alone and spelling his companion every half an hour or so as to keep up the most efficient progress and cut through a pair of beams in about 8 hours, equivalent to 3 sq. in. of steel per hour.

The lower section of the column, with its upper end about 3 ft. clear of the first floor, had already been seated accurately on the grillage beams and the next section about 6 ft. long and weighing a little more than 12,000 lb., was brought in through the first floor corridor on a hand truck, taken through the door in the enclosure, lifted by a differential hoist suspended from the second floor girders, lowered to position and connected to the lower section with web and flange cover plates, secured by turned bolts passing through reamed holes and having spring lock nuts. Steel shim plates were packed between the lower flanges of the old 24-in. I-beams and their angle bracket supports on the new column and satisfactory bearing was obtained by a pair of wedge-shape pieces on top, which were driven until they relieved the shores, after which they were securely bolted in position.

As the column weighed over one ton per lineal foot and because long lengths would be difficult to handle through the offices, it was, for the purposes of erection, made at the shop in two lengths for each story. The maximum weight does not exceed 16 tons. These were successively brought in, erected and connected as already described, the work being accomplished in the upper story inside small rectangular chambers like that in the bank. By this method the two new columns were carried up through the 6 old stories and all their connections satisfactorily made by a gang of about ten men in each of two shifts working altogether night and day.

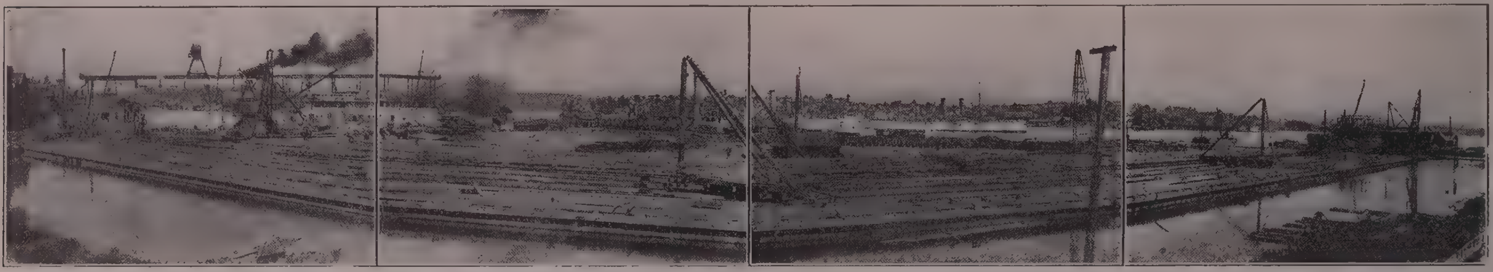
After the steel work was completed the ceiling and floors were restored, the decorations of the former were renewed, the columns were enclosed with terra cotta and were plastered and kalsomined so as to conform perfectly to the appearance of the rest of the room and make it impossible to distinguish if any new construction had been done there. One of the columns in the bank occupies a space in the cashier's railing previously used for a window, leaving a clearance of only 2 in. from the frame of another window, which was not all disturbed by the operations. One panel of the handsome bronze metal work was carefully removed and after the column was finished a special bronze panel about 2 in. wide was fit in between it and the adjacent window frames filling the space harmoniously, without the suggestion of any change of the original design.

Mr. Ernest Flagg is the architect of the building and Mr. O. F. Semsch, of his staff, the engineer, and Mr. E. A. Rogers the general superintendent under whose personal supervision this work was executed. The structural steel and ornamental iron work was manufactured and erected by Milliken Bros., Inc., Mr. W. R. Waterbury, general superintendent of erection, and Mr. W. Craig, superintendent in charge.

THE FUEL CONSUMPTION of the three 100-h.-p. gas engines composing the power plant of the Union Steel Screw Co., Cleveland, O., averages 11 cu. ft. of natural gas per horse-power-hour, the gas costing there 30 cents per thousand.

THE CONTRACTOR'S PLANT AND METHODS ON MARE ISLAND DRY DOCK NO. 2.

The navy yard at Mare Island, California, has at present a single stone masonry dry dock 400 ft. long and 122 ft. wide, which has long been inadequate to serve modern cruisers and battleships. Over ten years ago an appropriation for a new dock of adequate size at that time was made by Congress, but various circumstances have greatly delayed the construction of this second dock. The original plans for the latter contemplated a timber structure, and a contract for the construction according to these plans was awarded. Before much actual construction had been undertaken under this contract, however, the decision was made to build the dock of concrete instead of timber, the structure to be approximately 130 x 790 ft. in plan at the limits of the masonry. After work had been in progress for some time, according to the revised plans, the contract was abandoned, owing chiefly to the exceedingly hazardous and somewhat unexpected conditions encountered. Following a considerable delay thus involved, the contract was again awarded to the Scofield Construction Co., of Philadelphia, Pa., which company has sufficiently overcome the unusual difficulties presented by the site that the completion of the dock within a year may reasonably be expected.


General View of Completed Caisson for Mare Island Dry Dock No. 2, Showing Position of Existing Dry Dock.

The Mare Island navy yard is on the right bank of Napa Creek, a tidal estuary from San Pablo Bay, which is a part of San Francisco Bay, the navy yard being about 25 miles from the Golden Gate. Napa Creek has a channel depth sufficient to accommodate the largest vessels of the navy. The navy yard is on an area of comparatively low, flat ground, some of the buildings, in fact, having been erected partially on reclaimed land. The existing stone masonry dry dock was built in an excavation in a strip of ground that rose just above the high-tide level on the downstream side of the main buildings. The axis of this dock is normal to the channel of Napa Creek, the entrance being in a line with a sea wall built to hold the channel along the yard.

The site of the new dock is immediately downstream from the existing one, its long axis making an angle of about 30 deg. with the channel of Napa Creek, while the upstream end of the site is close to the shore end of the present dock. Although the latter was built under comparatively favorable circumstances, the conditions prevailing at the site of the new dock are unusually adverse. The existing stone masonry dock was built at a point where shale came to the surface, but this shale, like all the adjacent ground, contained pockets of rotten sandstone, sandy, blue clay and conglomerate. The dock was built directly on an excavation in the shale, piles being used only as necessary in the pockets in the latter.

The land end of the site of the new dock for a distance of 200 ft. toward the off-shore end was underlaid at a depth of 20 to 40 ft. from low-water level with a mixed formation in seams at an angle with the vertical. These seams contain disintegrated sandstone, stiff yellow clay and shale, sandy yellow clay, sandy blue clay, with a few occurrences of cemented gravel, or conglomerate, which is water-bearing and scours very easily. Some pockets of a sandstone that disintegrates almost immediately in water, and resembles quicksand, were also found in the formation. The latter was overlaid with about 12 ft. of peat, that was covered with what is locally termed tule mud. This mud has been deposited from the waters of Napa Creek, which, together with all the adjacent tidal waters, are heavily charged with particles of clay of remarkable fineness, that have been brought down the various tributary streams from hydraulic mining operations on the headwaters of these streams. This finely-divided clay moves continuously with every tide, but is rapidly deposited in quiet water, where it forms a perfectly instable stratum that has practically no angle of repose, and little capacity for carrying loads. At the land end of the site the tule mud was covered with spoil from the excavation for the existing dock.

From the termination of the mixed formation, 200 ft. from the land end of the site, to the off-shore end of the latter, the peat was underlaid by blue and yellow clay in irregular inclined strata, the yellow clay in places approaching the hardness of shale, and some of the blue clay containing much sand. Beyond the entrance of the dock site the hard material dips very quickly, and at a point 100 ft. from the end of the site 100-ft. piles could not be driven anywhere near refusal. Added to these adverse soil conditions is the necessity, imposed by the site, of building the dock entirely off shore in water 40 ft. deep at low tide, after the dredging required had been finished, and with a maximum tide variation of 8 ft., the average difference between tides being about 6 ft.

The dock is to be built entirely on a foundation of round piles, over 12,260 of these piles being required. The sub-grade of the concrete at the entrance to the dock is 37.75 ft. below low-tide level, and 36.75 ft. below that level at the head of the dock. The site was dredged accordingly, so the piles could be cut off at levels that would bring their heads well into the base of the concrete. Before this dredging was done the site was divided into four sections. The section at the off-shore end of the site was then dredged to a depth of 2.5 ft. below the sub-grade of the concrete, as an experiment, to determine the depth required to avoid any additional excavation when the piles had been driven. After the first rows of piles were driven in this section, 4 ft. apart on centers in one direction, and 3 ft. apart in the other, soundings demonstrated that the bottom had risen 1.25 ft. Since for a width of 24 ft. along the longitudinal center line of the dock, and along both sides of the latter, piles had to be spaced 18 in. apart on centers, the conclusion was reached to overdredge 1.5 ft. each succeeding section toward the head of the dock. The average total rise after driving the intermediate piles was only 2 ft., although in the area of greatest penetration, toward the head of the dock, the bottom came up to, and in some places above grade.

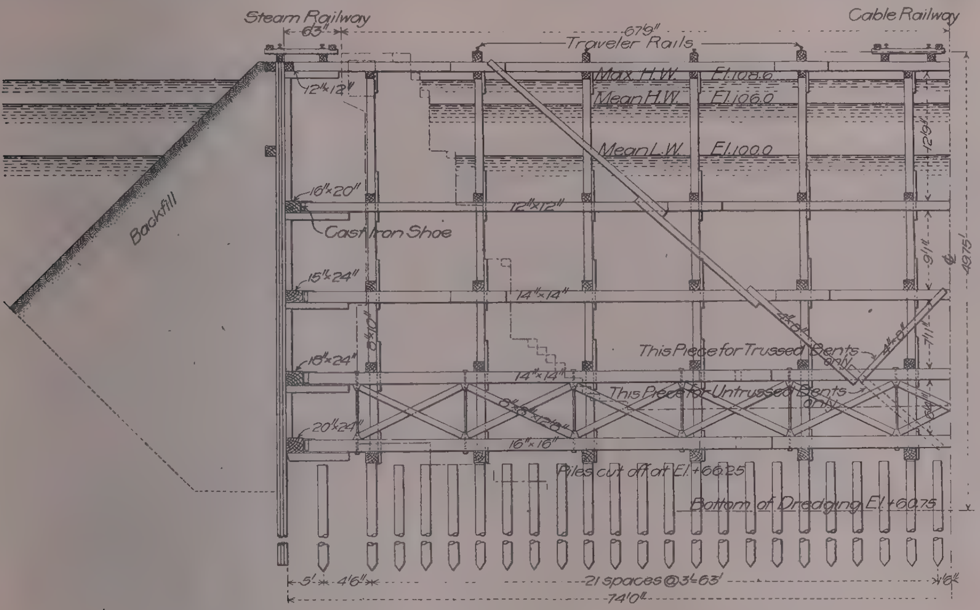
The original contractor attempted to unwater the site of the dock by constructing an earth-fill and sheet-pile cofferdam of the ordinary type around the off-shore end and a part of the off-shore side. This cofferdam was 50 to 200 ft. from the immediate site of the dock, closing with the main land at one end and with a strip of made ground back of the sea-wall at the other end. It consisted of two rows of sheet piles and round piles, with the space between the rows filled with earth. Dredging of the dock site had scarcely been well started after this cofferdam was finished before the latter began to show signs of weakness, and then failed entirely. An attempt was afterward made to build a second cofferdam of the same type, but this one also failed, and the contract was abandoned.

When the construction of the dock was undertaken by the Scofield Construction Co., it was evident, from the soil conditions, that some departure from usual methods of handling similar work would have to be adopted. The employment of a cofferdam similar to the one outlined by the original contractor would have required the sides of the excavation to be lined closely with sheet piles, with the latter held in place by a bank of good soil, or tied back by means of heavy chains or cables anchored at a sufficient distance to prevent the banks from slumping. Such construction would have been necessary to protect the shop buildings of the navy yard adjacent to the site, since it had been determined that the banks would otherwise fall away continuously, due to the sagging of the soft underlying mud. As a result of the movement of the latter, when not confined, vertical cracks would appear in the surface soil in the vicinity of the site, causing continuous land slides. Such a cofferdam would also necessarily have been built 100 ft. from the off-shore end of the site, where hard material is 80 to 90 ft. below low water, and where its construction would have required an enormous amount of fill to give it sufficient stability.

The type of construction used to avoid such a cofferdam and to overcome the adverse conditions of the site is believed to be entirely unique in its application to a project of this magnitude. Briefly, this construction consists of a row of vertical, tight sheet piling extending entirely around the site, 9 ft. outside the limits of the masonry lines of the dock. This continuous row of sheet piling, 1,960 ft. long, is practically watertight against a head of nearly 50 ft., that is brought on it at high tide when the water is pumped out of the enclosed space. The piling thus forms an immense open caisson, the sides and ends of which are braced apart by a crib of framed timbers in five horizontal planes. This caisson, including the crib of framed braces, contains approximately 4,000,000 ft. B. M. of lumber.

Following the decision to build the dock in a caisson of this type, the construction work was necessarily divided into several distinct operations. The site had to be dredged from an existing depth of from 20 to 30 ft. below low water to a uniform minimum depth of 40 ft. Then the 12,260 round piles had to be driven and sawed off about 36 ft. below low water. Following that, the crib of framed timbers was built up in the water over the site and lowered accurately into place on the tops of the piles 36 ft. below the low-tide level. The sheet piles forming the sides of the caisson were next driven around the sides and ends of the crib, after which the water in the caisson was lowered by pumping and preparations were being made at the time this description was prepared to start placing concrete in the dock. Although these various sequences of operations were accomplished as noted, the specially difficult soil conditions, the long delays due to circumstances entirely foreign to the work and the extreme magnitude of the various features of the undertaking have rendered their execution exceedingly expensive.

The dredging was done with a suction dredge equipped with a 20-in. centrifugal pump. The suction pipe of this dredge was carried by a ladder frame, which was long enough to drop the cutters to the full required dredged depth. The discharge from the pump was carried through a 20-in. steel pipe to an area some 3,000 ft. down stream. The 12,260 piles which have been driven to provide a foundation for the dock are all Oregon fir and were delivered to the site in sailing schooners. Two floating pile-driver outfits were rigged especially to drive the piles. Each of these outfits was mounted on a 26 x 73-ft. scow built in connection with the work. As the piles all had to be followed under water, to a depth of 40 ft. or more, each scow was rigged with 42-ft. leads shod with steel plates and arranged so sliding gins 88 ft. long could be operated vertically in them.



Cross Section of Framed Timber Crib, Mare Island Dry Dock No. 2.

These gins consisted of two 12-in. 31.5-lb. I-beams, with one side of the web of each beam bearing against and sliding on the steel plate protection on one side of the leads. On the inside of the web of each beam was riveted vertically a pair of 6-in. 13-lb. channels, placed back to back with the two pairs of channels spaced to form leads of proper width for the guides of a No. 1 Vulcan steam hammer, with which the driver was equipped. An I-beam was also riveted vertically to the rear flange of each of the I-beams sliding in the leads to stiffen the latter beams. These stiffener beams were cross-connected in the rear with box yokes placed vertically to allow the hammer and a follower to clear. A 40-ft. stick of blue gum timber, shod on both ends with heavy cast-iron caps, was used as a follower. The steam hammer was lashed to the top of this follower, a block of lignum-vitæ being placed between the follower cap and the hammer. The sliding gins were arranged so the follower was always supported horizontally at two points, one near each end. A Lidgerwood hoisting engine, with three drums, one to raise and lower the gins, one to handle the piles and the third for handling the hammer and follower, was placed with a steam boiler on the opposite end of the scow from the leads.

The 12,260 piles were driven in 40 to 50 ft. of water and cut off 36 ft. or more below low tide in a space 148 x 810 ft. in plan, with the result that they are very close together. The maximum longitudinal spacing is, indeed, 4 ft. apart on centers, while the maximum transverse spacing is only 3 ft. apart on centers. Extra rows of piles are placed between the four regular rows on each side of the long axis of the dock, between the eight outer rows under the walls and at other points, so that over much of the bottom the piles are as close together as they could be driven.

The necessity for accurately locating each pile according to this excessively close spacing required the adoption of a special method, in order that the driving could progress without being continuously delayed by the instrument work. Large working drawings of the foundation plan were therefore prepared at a scale of ¼ in. to the foot, showing the exact location of each of the 12,260 piles. This plan was divided into four sections by transverse lines starting at the head of the dock. The center lines of the longitudinal and transverse rows of piles were then drawn, paralleling, of course, the two axes of the dock. The center lines of the longitudinal rows were numbered consecutively in both directions from the longitudinal axis of the dock, starting with the latter as 1 and continuing to 44 for the number of both outside rows. The transverse rows were numbered consecutively from the land end of the dock to the off-shore end. Any pile could thus be immediately located by giving the numbers of the intersecting center lines of the rows in which it was situated, the corresponding intersections on the two sides of the longitudinal axis being designated by North and South, as North 90-40 and South 90-40.

The numbers of the rows were accurately spaced on 10-in. range boards according to the actual full scale of the work, with black figures 6-in. high on a white ground. These range boards were then placed around the site in a position corresponding to the numbers painted on them. The boards were nailed to firmly driven piles, or posts, entirely outside the limits of the work. When the location was such that they could not be placed parallel to their respective axis, the numbers were projected and laid off with greatest accuracy. In order that the figures might also be seen at night as well as in the day light, a board painted white was placed 1 ft. below and 4 ft. in front of the range boards to act as a reflector for 16-candle-power incandescent electric lamps spaced about 4 ft. apart.

A special engineer's transit stand was built, in order that the instrument could be utilized to the best advantage in connection with the range boards placed around the site. This stand had four steel-angle legs, attached at the top to a ring on which was mounted a specially-built transit base having four gimbal bearings at the quarter points of the circle. A heavily-weighted iron pendulum was attached to the base of the transit, the point of this pendulum just clearing the floor. The special transit stand was firmly attached to the floor of the pile driver scow, 10 ft. in both directions from the center of the pile-driver hammer. The numbers on the range boards around the site were also offset this same distance to produce the proper relations. A brass plate, with two intersecting perpendicular lines marked on its surface, was attached to the floor under the center of the transit. By means of the lines on this plate and the pendulum on the transit the relative level of the floor of the scow could be determined. When this level was out of the horizontal a truck load of pig iron was moved from place to place on the scow to right it. The transit was covered with a house large enough to provide for the transitman to work easily, a window being placed in each of the four sides of the house.

The pile driver scow was first placed relatively in the position in which it was to work and was then moored by six lines, by means of which its movements and location could be accurately controlled. Three of these lines were at one end and the other three at the opposite end of the scow. One line of each set of three extended on the long axis of the scow to an anchor in front, or in the rear of the latter. Each of the other two lines extended from one corner of the scow, normal to the axis of the latter, to an anchor at the side. The two end lines were each on a spool of the pile-driver hoisting engine, while the four side lines were each on gypsy winches. With this arrangement of the six lines the least movement of the scow desired could be obtained and the scow held accurately in any position.

The location of the next pile to be driven in each case was determined by the numbers on the range boards. The transitman could sight on the number on one side and signal to the man handling the lead and rear mooring lines until the scow was pulled ahead, or back, the proper amount. The side lines could then be used to obtain the exactly correct position, which was determined by the transitman with two sights and two reverses. This method proved perfectly accurate and was used with great rapidity soon after it had been adopted.

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The piles for the dock as delivered ranged from 40 to 65 ft. in length. They were driven to various penetrations, depending on the soil encountered, the minimum penetration being about 12 ft. and the maximum 46 ft. During most of the work two 8-hour shifts were used continuously, and for a period of exactly three months an average of 35 piles were driven to each 8-hour shift. The best day's work was 74 piles in 8 hr., but this was offset by days when both drivers were out of commission due to the steel gins being badly twisted by landing on some pile previously driven. This twisting was also caused by the 15-ton load of the gins, hammer, follower and pile escaping from the hoisting engineer, due to the lightness of the hoist installed. The method adopted to determine the location of the piles proved specially advantageous to the remarkably rapid work done under these conditions.

A complete record of the conditions regarding each pile was made at the time the pile was driven. The number of the two intersecting center lines determined the location of the pile, while the length and the diameter of both ends could be measured readily. The variation of the tide, the follower reading, the depth of the point of the pile below low tide, the penetration, length of the pile in place, amount to be cut off, number of blows to the last 5 in. of penetration and the total number of blows were measured and recorded as the driving progressed. This work was all done by a government inspector and checked by an engineer for the contractor. The records were preserved in field note books, so that the data regarding each of the 12,260 piles was available for use later.

The piles in the regular longitudinal rows were driven over the entire site first, and then in the intermediate rows toward the center and along the sides. By working the drivers straight along one row of piles in this manner the amount of side shifting was greatly reduced. At the same time, the piles could be sawed off to the proper grade much more readily.

A 26 x 73-ft. saw scow was rigged specially for use in cutting the piles off 40 ft., or more, under water. This scow carried at one end a pair of 70-ft. leads in which a 16 x 16-in. timber spud, 70 ft. long, was operated. A vertical 4-in. shaft mounted in bearings on this spud carried a circular saw at the lower end. Saws of such sizes as could be procured were used, ranging from 40 to 50 in. in diameter. The saw shaft was belt-driven, 3 ft. above the deck of the scow, by a steam engine mounted with its boiler on the scow.

One of the gimbal-hung transits was placed on the scow in the same position as that occupied by the one on each pile-driven scow. The saw scow was also located by means of this transit, and was moored by six lines in exactly the same manner utilized in connection with the pile-driver scows. A level target nailed to the spud was used to determine the position of the saw by means of an instrument on the shore.

Serious difficulties were often encountered in sawing off the piles at the considerable depths, resulting in no less than fifty of the circular saws being broken. The chief trouble in this connection was occasioned by waterlogged pieces of piles being encountered by the saws. The original contractors had furnished 7,000 piles which had been in the booms three years, added to which was a delay of six months after some of the piles had been driven before cutting was started. The waterlogged pieces would drop in front of the saw, and as the saw scow was kept moving continuously the saw would rise up on these pieces sufficiently to break it, or would be caught so the movement of the scow would break it.

While the method of pursuing the work greatly reduced the possibility of missing piles, a diver was used constantly during the time the sawing was in progress to locate any piles that were missed and to determine whether accurate cut-off levels had been obtained. Wherever a pile was found to have been missed by the diver, the latter attached to it a line carrying a buoy in order to locate it for the saw scow.

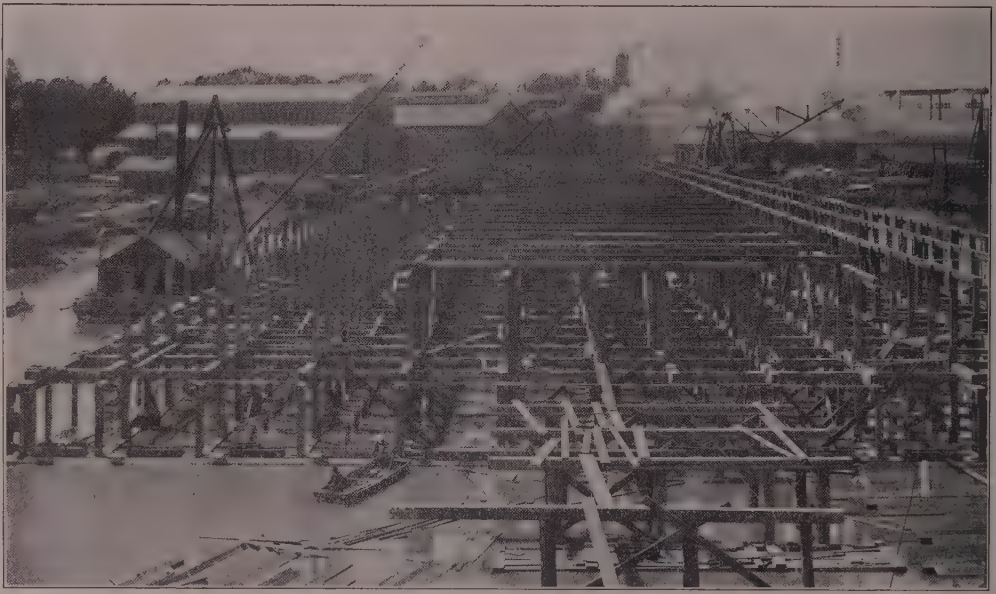
A floating wooden platform, 3 ft. wide and 160 ft. long, was used to assist the diver in determining the piles that were in error. This platform had guides mounted on it, at intervals of 16 ft., in each of which guides a vertical pivoted rod, 12 ft. long, operated through a hole in the platform. Each rod had a wire long enough to reach the bottom attached to its lower end, and to each two adjacent wires was attached horizontally a 16-ft. length of gas pipe. The row of lengths of gas pipe were all hung at the same elevation from the floats, the depth being altered to correspond with the tidal variation, by means of tide gauges on the platform. As the platform was moved along, any pile too high would immediately be indicated by the change in the position of the adjacent rod, due to the suspended pipe striking the pile. The resulting accuracy was quite remarkable, as only a single pile was found to be enough too high to interfere with the framed crib of the caisson when it was sunk.

The delay involved in securing the machinery and materials for the saw scow is an indication of the hindrances that have been offered to the work from time to time by agencies entirely foreign to the latter. The machinery and the materials were ready to be delivered the day of the San Francisco disaster, April 18, 1906, but were destroyed in the fire, with the result that duplicates were not obtained until the middle of the following July. In a project of this kind where the work must be handled in a series of operations, one following the other, if one of these operations is delayed the whole work is interrupted accordingly.

Work was started on the crib of the caisson as soon as possible after the piles for the dock had been driven. The crib consists of five horizontal courses of transverse and longitudinal timbers, with the timbers in each course braced apart from those in the adjacent courses by posts, and with the whole structure built as a unit, the same as a framed steel structure. The general features of the construction are shown in accompanying illustrations. The longitudinal rows of timbers are 12 ft. apart on centers and the transverse rows 10 ft., the crib taking bearing on the piles through 2 x 12 x 48-in. blocks under the lower course of longitudinal timbers. The timbers in the bottom course are all 16 x 16-in. in cross section, those in the next two courses, 14 x 14 in. and in the two upper courses 12 x 12 in. The walings along the sheet piling of the caisson are 20 x 24 in. in cross section for the bottom course; 18 x 24 in. for the second course; 15 x 24 in. for the third; 16 x 20 in. for the fourth, and 12 x 12 in. for the top course. The two lower courses are 10 ft. 1 in. apart on centers; the second and third are 9 ft. 1 in.; the third and fourth, 10 ft., and the fourth and fifth, 11 ft. 10 in. The posts between the courses are 8 x 10-in. timbers in all cases.

The two center rows of longitudinal timbers in the bottom course are braced together by a horizontal Howe truss. The first and second courses of transverse timbers are also braced together at every fifth row by a vertical Howe truss. Sway braces extending from the bottom to the top course of the crib are placed at the same intervals as the vertical Howe trusses. The various timbers in the different courses are all spliced to make continuous members, and at all intersections of the horizontal and transverse timbers the posts are bolted to the timbers in both directions. In all cases machined bolts were used. Where the horizontal timbers take bearing against the walings a special cast-iron shoe was used to distribute the load on the walings, in order to reduce the fibre stresses and prevent crushing.

The timbers of the crib were framed before being delivered to place in exactly the same manner that is followed in fabricating the members of a steel-frame structure. Since the crib alone contains over 2,600,000 ft., board measure, of lumber, this method was imperatively necessary. A 32 x 120-ft. scow was rigged with a stiff-leg bull-wheel derrick and a swinging 50-in. circular cross-cut saw to cut the timbers to the proper length. This scow was moored adjacent to a 50 x 220-ft. timber-framing wharf, which was erected just outside the remaining portion of the original cofferdam. The timbers were rafted up to the scow, lifted on the latter by the derrick, sawed and dumped back into the water on the wharf side of the scow very rapidly. All of the necessary cutting was done and the holes for the connections were bored on the framing wharf. The splice timbers were also bolted to one of the two members to be spliced. A motor-driven saw was installed on the framing wharf for use in cutting planks and small timbers. After the framing had been done the timbers were dropped into the water again and rafted to the site of the crib. Each timber was marked before it left the framing wharf so its designated position could be determined readily when it arrived at the site.



Erecting Fifth Course of Crib Timbers, Mare Island Dry Dock No. 2.

The first work done in building the crib was to drive a row of clusters of piles along each side of the site. Each of the clusters contained three piles, the clusters being spaced 40 ft. apart and driven so as to come at the ends of transverse rows of timbers. A 16 x 16-in. timber, 24 ft. long and extending 14 ft. below low tide was attached vertically to each pile cluster to act as a guide for the crib. The two parallel rows of guides were thus located so two horizontal courses of the timbers of the crib were always between the ends of the guides during the erection work.

The leads were then removed from the pile-driver scows and a stiff-leg A-frame derrick, with its 40-ft. mast and 80-ft. boom revolved by a bull wheel, was placed on each of the scows. These two derrick scows were utilized throughout the construction of the crib to handle the framed timbers into place from the rafts in which they were delivered at the site.

The first framing done on the crib was to assemble the timbers of the bottom course to about one-third the width of the crib for about two-thirds of the length of the structure. This work was done with both derrick scows working in conjunction. The remainder of the timbers in this part of the first course were then placed and the course carried out to the end; the posts and trusses between this course and the second course were being erected at the same time. The erection of these posts and, in fact, of all the posts in the crib was simplified greatly by bolting one of the splice planks to the horizontal timber and the other to the post, before the latter was erected.

The balance of the crib was built as rapidly as the lumber could be obtained and framed. When the first course was finished it floated well out of the water and was not submerged until the second course was practically placed. As the addition of the third course failed to sink the second one—a condition which had been foreseen—200 tons of pig iron were distributed over the timbers of the third course. When the fourth course was built 400 tons more of pig iron were distributed over it, but on the completion of the top course the fourth one was still at the surface of the water. Finally, after placing a total of 1,800 tons of ballast of various kinds on the crib, the latter was sunk nearly to position.

Some delay was encountered, however, in firmly seating the lower course timbers on the pile heads at the lower end of the cofferdam, due chiefly to silt which had accumulated to a depth of 3 ft. over the heads of the piles. In two other places the peat had slumped into the dredged area and had to be removed with an orange-peel bucket working through the pockets of the crib, and by a hydraulic jet. After the fourth course was under water a few inches in depth of submergence was gained every 24 hr. with each succeeding extreme low tide. The crib was quite instable when the fourth course became submerged, as it had only the buoyancy of the posts to hold it in equilibrium. For that reason, enough ballast could not be placed on the lower end of the crib to hold it in the mud, as the whole structure had to be kept level on account of the rise and fall of the tide. When the crib came within 1 ft. of the piles enough weight was added to the lower end to force it through the soft silt. There was then only one high spot where a single pile was partly cut off, the stub sticking up 7½ in. too high. When this was removed the crib sank true to grade and accurate as to location. The rows of timbers and the walings were as true and straight as though the crib had been built on land, as may be seen from an accompanying illustration, and all of the walings were plumb one under the other.

The sheet piling forming the sides of the caisson consists of 12 x 12-in. timbers, each pile having a total length of 60 ft. As timbers of that length would have been very expensive and difficult to obtain, 34-ft. and 26-ft. lengths were used, the butt joints between the two timbers of the piles being staggered and caulked with oakum.

The sheet piles were practically all assembled and driven in pairs, thus reducing by nearly half the number of pieces to be handled. The two abutting sides of the piles of a pair were not planed, as this would have cost about $6 per 1,000 ft., and the benefit derived was not considered to compensate the expense involved. Two strings of spun yarn were, however, placed in the joint between the piles of a pair, and the sticks pulled together with clamps and machined bolts, so that even with curved piles as good a joint was obtained as though the timbers had been planed. A tongue and grooved joint was made between the pairs of piles by means of splines spiked to the timbers. A 3 x 12-in. plank was cut into three beveled pieces to make each joint, two pieces being spiked to one pile to form the groove and the third piece to the adjoining pile to form the tongue of the joint. Two strands of spun yarn were placed under each spline to assist in making a water-tight joint.

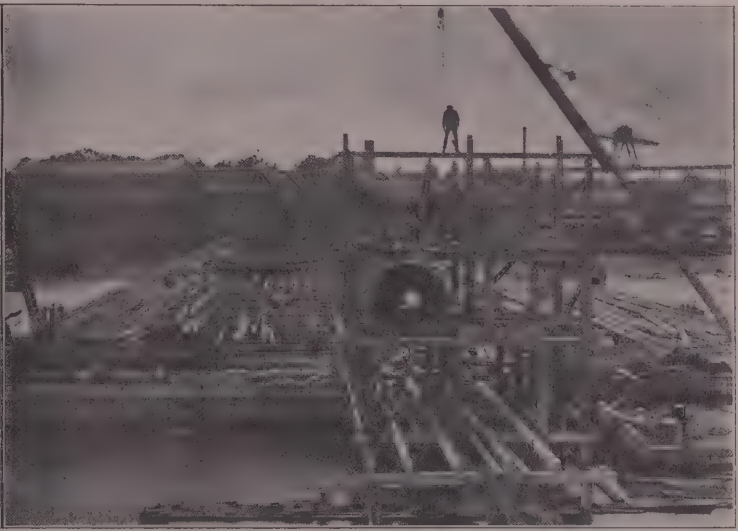
The built-up sheet piles were each 12 x 30 in. in cross section, so the leads, hammers and so forth had to be rigged specially to drive them. The leads were removed from the pile-driver scows and widened so they could be used in driving the sheet piles. These leads were set on skids on the top course of timbers of the crib and were moved on greased ways instead of rollers. The same No. 1 Vulcan steam hammers used on the pile-driver scows were also used again in driving the sheet piles. The hammers' guide was extended to fit the wide leads by bolting a cast-iron chair to each side of it. A special driving cap was also built for the hammer, a block of lignum vitæ being used between this cap and the head of the sheet piles.

The sheet piling was driven around the entire caisson, a total length of 1,960 ft. of sheeted wall 60 ft. high, in 30 working days. Three-quarters of the sheet piles were driven in good blue or yellow clay and the remainder in the harder formations at the head of the dock. The piles in the clay were driven practically to refusal, or approximately 24 blows to the last 6 in. of penetration; in the softest places in this clay the piles were allowed to stick up 3 ft. over night, after which three blows of the hammer were required to start a pile, the succeeding blows each giving a penetration of about ¾ in. until the pile was in the full length. The compression in the bottom was so great that when a pile was driven down to the top waling of the crib the adjoining piles already driven would rise 1 to 2 in. The average penetration in the clay was 12 to 14 ft. The driving through the hard materials at the head of the dock was much more difficult, however, single 12 x 12-in. piles being used in this locality. The average penetration of these piles was 7 to 10 ft., with a minimum of 5 to 6 ft., except in one or two isolated cases where small pockets of disintegrated sandstone or boulders were encountered and a penetration of about 3½ ft. was obtained.

While the sheet piling was being driven a diver was used to inspect each day's work the succeeding morning, any openings below the water line being marked, boarded over and later covered with canvas. There were comparatively few such openings, not more than a dozen in an entire 800-ft. side of the cofferdam. The long walls formed by the sheeting were also in remarkably straight lines, practically none of the piles being deflected in them and the walls being entirely continuous.

After the driving was finished the entire cofferdam was further carefully inspected in order that all openings and cracks might be closed. A patch pile or piles was placed wherever the diver found any indication that the splines had been turned away from the piles, even if the opening was only 1 in. wide at the mud line, since such an opening under the 48-ft. head to be brought against the sides of the cofferdam would have produced dangerous scour. In places the piles went in at the bottom in driving, thus bringing a heavy strain on the inside top waling of the crib which occasionally split the corbles and pulled them away from the transverse sill, but tie rods were sufficient to pull these into shape. In four other places, with a total length of about 90 ft., the piles were deflected outward from the walings at the bottom by striking obstructions. In only one case was this departure abrupt, the pile turning sideways sufficiently to necessitate a patch. At the other places the deflection was in the shape of a bow, the maximum departure in the middle of this bow being about 10 in., although the sheeting was continuous and tight. Where the sheeting had departed in this manner the space between it and the two lower courses

Erecting Elevator Cages for 15-Inch Centrifugal Pumps.



Completed Caisson with Mixing Tower in Foreground.

of waling timbers was filled out with blocks, which were cut to proper shape on the surface and then placed by a diver. Since from the nature of the bottom it was possible for the piles to deflect only slightly under stress this filling was done carefully in all places where the pile did not touch the waling.

The portion of the piles bearing against the walings of the crib acts as a continuous beam when the water is pumped out of the cofferdam. The length between the lowest waling and some point of support in the mud was also known to be a part of this continuous beam, if that point of support could be determined to be sufficiently rigid, as it evidently was from the driving. In order, however, to locate accurately the line of support for the lower end of the sheet piles, the clusters of the round piles used to support the guides of the crib were snapped off. The lowest grade at which these piles broke was approximately at the dredging line, which demonstrated that the part of the sheet piles below the lowest waling also acts as a continuous beam, with a maximum span of 12 ft. between the two lowest supports, which was assumed to be the worst condition. A section of pile tested under a 12-ft. span, with one end of the beams free and the other end partially fixed, carried a load of 5,000 lb. per square foot with a maximum deflection of 1 in., while the maximum load on the sides of the cofferdam is only about 3,000 lb. per square foot and is distributed under more favorable conditions.

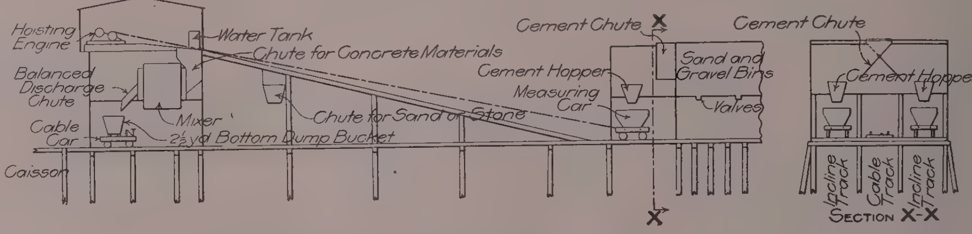
After the sides of the cofferdam had been made as tight as possible under water, pumps were started to remove the water from the enclosed space in order to locate further leaks and to determine the strength of the structure. As the water level was lowered such few leaks in the sheeting as occurred were plugged, and eight 3 x 3-ft. flood gates, which had been placed in the sides and the outer end of the cofferdam, were caulked. Two 15-in. centrifugal pumps lowered the water to the fourth course of timbers from the top of the crib, and after that depth was reached two 8-in. centrifugal pumps were added. Three-quarters of the total leakage up to this time was through the butt joints between the two timbers of each sheet pile. The hard driving had forced the oakum out of these joints, which it was then evident would have been better with a pin connection as a stop-water. The first row of these butt joints was plugged with shingles from the inside after the water had been drawn down, and then the water was lowered to below the second row, 26.5 ft. below mean tide level, where one 15-in. and one 8-in. pump held it until those joints were also plugged.

Meanwhile, a 1½-in. opening between the regular sheet piles and a group of four patch piles, bolted together, near the head of the dock scoured a V-shaped hole, 9 ft. deep, on both sides of the sheeting in the conglomerate formation. This hole, when filled with concrete in bags on the inside, and clay on the outside of the sheeting, gave no further trouble. The following day another leak occurred near the head of the dock, where five of the sheet piles had a penetration of from only 2½ to 3½ ft., having landed on a pocket of disintegrated sandstone. Irregular strata of shale and clay run diagonally under the sheeting close to this point, with occasional pockets of this disintegrated sandstone, which slakes rapidly in water or in air. The water had undercut through one of these pockets, and the leak, which appeared out some 25 ft. from the sheeting in the cofferdam, was of such magnitude that the flood gates were opened and the cofferdam allowed to fill. Afterwards, 110 cu. ft. of concrete were placed in this hole inside of the sheeting, and 10 cu. yd. outside before it was filled.

Seven-eighths of the total length of the sheeting walls were driven 12 to 14 ft. in good clay, in which no undercutting would occur, and in this part of the cofferdam the only danger was from an opening in the sheet piling acting as a jet to cut its way down through the clay. These places had been detected and soon closed, so no trouble was anticipated from them. The decision was made, therefore, to puddle around the outside of the sheeting at the head of the dock for a distance of about 250 ft., where the piles had penetrated 7 to 10 ft., but were in the broken, irregular formations of clay and shale. Meanwhile, the fissure in the disintegrated sandstone, which had cut down 9 ft. below grade, had to be carried 8 ft. farther before the bottom of the pocket was reached. This hole was then filled with concrete in bags by a diver, and the puddle placed over it.

When the puddle had been placed around the head of the dock to a depth of 6 to 10 ft., the water was again pumped out of the cofferdam. Three pumps, an 8-in. and two 15-in. centrifugals, required nine days to lower the water level to the heads of the piles. It had been anticipated that less time than this would be necessary to unwater the cofferdam, but the strips of canvas over many of the cracks had rotted, since the canvas only lasts about two weeks under water. These openings were therefore wedged up on the inside with shingles as the water was pumped down.

During the period of pumping from the second course of timber in crib down, a patrol of four men was constantly searching for signs of scour with long poles. The water level was held down to the pile heads for two days with no signs of a bottom leak, and no evidence of weakness in the cofferdam. A scour then occurred near the head of the dock in a pocket of conglomerate underlying a bed of blue clay. This conglomerate was washed out, leaving the clay supported against the sheeting, and appeared 24 ft. inside the latter. Efforts to stop the leak were of no avail, so the flood gates were again opened in order to fill the cofferdam and prevent any serious consequences.



General Arrangement of Concrete Plant, Mare Island Dry Dock No. 2.

At the time the cofferdam was flooded there were no evidences of any other scours or leaks, the water level being held down by one 15-in. centrifugal pump. The significance of this condition can scarcely be appreciated, as the sheeting offered a wall, 1,960 ft. long, with about 11 miles of joints in it, against which there was a sheer head of water of 48 ft. at high tide. Practically the only leakage into the cofferdam was through cracks below the lowest course of walings, which did not produce sufficient water to flush out the accumulation of silt over the piles. In fact, four 4-in. syphons and two 4-in. discharge steam pumps supplying six lines of 4-in. hose were all discharging water into the off-shore end of the cofferdam for this purpose when the latter was filled the second time. The water which leaked into the cofferdam, added to that from the two 4-in. pumps and the four syphons, was not more than the 15-in. centrifugal pump could handle.

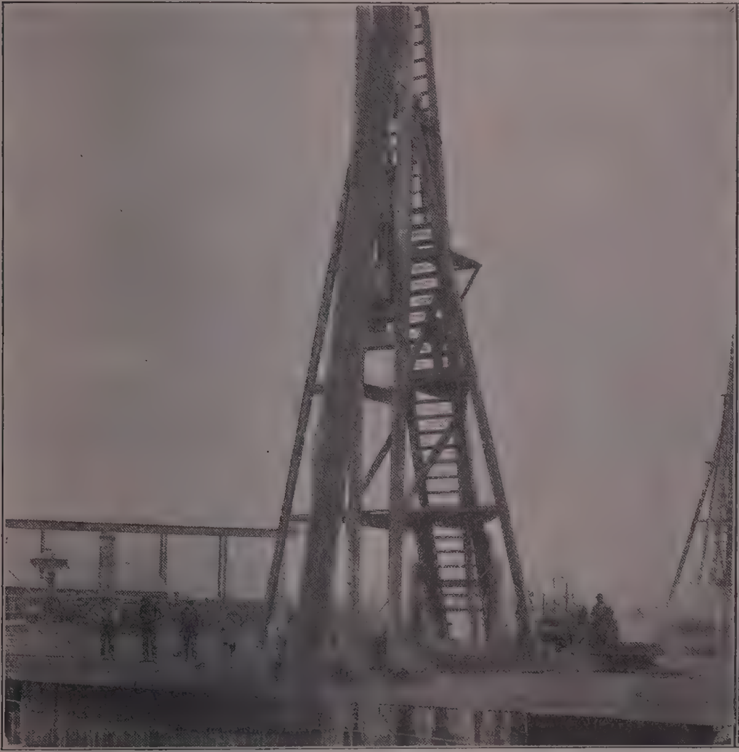
The strength and general tightness of the long, high walls of the sheet piling having thus been fully determined, it was evident that underscouring through pockets in the unusually irregular strata of clay and shale at the head of the dock was the chief danger to be overcome. By any other means, except in an open caisson, the mud and silt which had accumulated over the heads of the piles to a depth of as much as 6 ft. would have to be removed under water and the bottom of the cofferdam sealed with concrete in the same manner, all of which would have been done with great difficulty. The decision was accordingly made to place puddle back-fill around the outside of the sheeting up to the low-tide level, thus greatly reducing the head against the sheeting, and the possibility of underscouring in the irregular formations. This method had previously been contemplated, but it was desired to avoid it at this time, in order to make the fill while the concrete work was in progress, since the contract had been badly delayed, due to the inability to secure materials.

A borrow pit was opened in a hill above the shop building of the navy yard to obtain material for the backfill. This hill is an irregular formation of shale and clay, exactly similar to the material around the head of the dock. The material, when deposited around the sides of the sheeting, pushed back the silt, which had accumulated there to a depth of several feet, and settled into the stratum of black clay under this silt, forming a quite satisfactory puddle.

In all about 52,000 cu. yd. of the puddle was required to make the backfill up to low-tide level. A steam shovel was installed in the borrow pit and the material was delivered over the tracks in the navy yard in trains of 5 yd. dump cars. A track was laid along each side and the inshore end of the cofferdam to permit the material to be deposited directly in place. Various conditions in the navy yard hindered this work, but on an average 1,000 cu. yd. of material were delivered every 24 hr. over a single track ¼ mile long leading through the yard, with seventeen switches in this track.

After the fill had been carried up to low-water level, the two 15-in. pumps were started and the water level lowered to the tops of the piles in three days, exposing the mud which stood over the heads of the piles. This might appear to be too rapid work, but the cofferdam had been pumped out previously, so the sheeting had all taken bearing; as the fill had also been deposited through the water it was therefore thoroughly packed, so, on the whole, no danger was anticipated in removing the pressure from the inside of the cofferdam. It was not considered necessary to install additional pumps, since the small openings in the sheet piling had all been wedged when the cofferdam was pumped out before, so the latter was practically tight, the backfill making it even more secure.

During the 21 months which elapsed after the cofferdam was built, until it was finally unwatered, 18,000 cu. yd. of silt had been deposited, from the water, around and over the heads of the piles driven to provide a foundation for the dock. At the time this article was prepared the silt was being sluiced to the pumps at the land end of the dock. The bottom of the cofferdam was divided into three longitudinal sections of four panels of the timber crib each, with the intention of cleaning the mud from one side section and placing the concrete in the latter to a depth of 2 ft. Then the other side was to be cleaned and concreted, after which the mud would be cleaned from the four center panels and the concrete placed in them, thus forming a 2-ft. concrete seal over the entire bottom. The mud was loosened with jets from nozzles supplied by a reciprocating pump on top of the crib. Sufficient water to carry the loosened material to the pumps was admitted through gates in the sides of the cofferdam. By working laborers in three 8-hr. shifts, it was possible to remove, in this manner, 2,000 cu. yd. of material a day, with an 8-in. and two 15-in. pumps, the latter carrying 10 per cent solid matter in solution.


Driving the 60-Foot Sheet Piles in Pairs.

Sand and Gravel Pocket and Delivery Tracks.

Two 15-in. centrifugal pumps, on which dependence will be placed to keep the water level in the cofferdam lowered, are each arranged on an elevator cage so they can be raised and lowered with the variations in the water level, or lifted above the top course of the timbers of the crib. Each pump is placed on a 6½ x 10-ft. platform, built of 6 x 8-in. timbers, and is belt-driven by a 120-hp. electric motor on a platform 14 ft. above it, the two platforms being connected by eight 6 x 6-in. uprights, which are cross-braced thoroughly and form the cage. The latter operates in a timber guide frame, built up on the top timbers of the crib, and is suspended from this frame by a steel cable on triple purchase sheave wheels. The two guide frames are set at the inshore end of the cofferdam, where the discharge pipes can be dropped over the sides. Each cage can be readily raised and lowered by traveling derricks, which operate on top of the crib. The suction head is thus greatly reduced by being able to alter the position of the pumps, and danger of the pumps being submerged in case the cofferdam is filled suddenly is avoided.

Since danger of flooding the cofferdam will exist at all times under the most favorable circumstances that can be obtained, it is essentially necessary that arrangements be made to place the volume of over 80,000 cu. yd. of concrete required in the dock with all possible speed. To this end, a very complete material and concrete handling plant has been installed. The controlling features of the arrangement of this plant were to be able to pass all materials through it in as nearly a straight line as possible, and to insure a continuous output during three 8-hr. shifts under practically all conditions. As no suitable sand is obtainable in the immediate vicinity, one of the scows that had been rigged previously as a pile-driver outfit, was fitted up as a dredge to pump sand from the bed of the Sacramento River, 42 miles above the site. In that locality the bed of the stream is composed of a remarkably clean, sharp sand. The dredge has an 8-in. centrifugal sand pump, belt-driven by a steam engine, and can deliver 50 cu. yd. of sand an hour to scows under the operating conditions. The scows were towed to the dock by a gasoline tug until a larger tugboat could be placed in commission for the purpose.

The crushed stone is furnished by a quarry 24 miles distant on the shores of San Pablo Bay. It is loaded into 600-cu. yd. scows, which are also towed to the site.

An elevated storage pocket divided into two compartments, one for sand and one for broken stone, has been erected on a pile foundation, with its adjacent end about 150 ft. downstream from the dock, and with its longitudinal center line coincident with the longitudinal axis of the dock. The concrete mixing plant is a three-story tower against the off-shore end of the cofferdam. This tower is carried by piles, and has its transverse center line coincident with the longitudinal center lines of the cofferdam and storage pocket.

The elevated pocket is 30 x 300 ft. in plan, and rises to a total height of 32 ft. above mean low tide. It stands on eighty-nine transverse pile bents, each of which contains four piles ranging from 80 to 100 ft. in length. These piles were driven to a penetration of as much as 75 ft. in places without fetching up, as the stratum of blue clay underlying the site of the dock drops away at the off-shore end of the latter to an undetermined depth. Batter piles were driven on both ends of every fourth bent to prevent lateral motion, and as all of the piles under the structure assumed a comparatively large carrying capacity soon after they were driven, no apparent settlement or weakness has been detected when both pockets were fully loaded, bringing approximately 30,000 lb. on each pile.

A tight floor is erected over the caps of the pile bents, the bottom of the pocket being 7.5 ft., on the average, above this floor, as the inshore end of the pocket is 3 ft. lower than the off-shore end. The pocket is carried directly by four longitudinal rows of 12 x 12 in. timbers, spaced 4 ft. apart on centers in the rows. The two rows on each side of the center line are spaced 10 ft. apart transversely, in order to provide room between them for a standard-gauge track to be laid on the floor over caps of the piles.

The two compartments of the pocket are each 30 x 150 ft. in plan, and 12 ft. deep, each having a capacity of 2,500 cu. yd. The sides and ends of the compartments have 3 x 12-in. uprights lined with 2 x 12-in. plank placed horizontally. The bottom of the compartment is built in the shape of two longitudinal hoppers, with the center line of each hopper over one of the two longitudinal standard-gauge tracks laid on the floor over the pile caps. Two rows of 12 x 12-in. openings are placed in the bottom of each hopper, the openings being 10.5 ft. apart in the rows, and controlled by a double-lip under-cut gate operated by a hand lever from the track floor. These operating levers are at the sides of the track, where they can be reached without interference from a car on the track.

The scows in which the crushed stone is delivered have horizontal belt conveyors placed under a row of openings in their decks, which conveyors deliver to a bucket elevator carried by a boom. The latter is arranged so it can be raised and lowered, and has sufficient length to enable the elevator to deliver into the stone pocket. Two of the stone scows, each with a capacity of 600 cu. yd., are provided to insure a supply.

The sand is hoisted into the sand pocket by means of a ¾-yd. Hayward clam-shell bucket handled by a stiff-leg derrick traveling on top of the pocket. The derrick platform travels on a rail on top of each side of the pocket, and carries two derricks, one to serve scows on each side of the pocket. Each derrick is equipped with a 10 x 12 in. Lidgerwood engine, and can handle 35 cu. yd. of sand an hour.

The cement used in the concrete is made in the mill of the Standard Portland Cement Co., at Napa Junction, 6 miles from the work, and is delivered to the dock in a scow having a capacity of 2,000 barrels. This scow is covered with a tight shed to protect the cement from the weather. A cement storage shed, with a capacity of 12,000 barrels, has also been erected on the edge of the shore adjacent to the inner end of the sand and stone pocket. The cement scow is moored in the slip between the pocket and the storage shed, where it can be reached by a 65-ft. boom stiff-leg derrick mounted on a section of the old earth-fill cofferdam. The location of this derrick is such that it can reach cars on a track leading into the cement shed, or a 4 x 6-ft. hatchway in a floor over a 15 x 30-ft. working platform level with the floor of the pocket, at the inshore end of the latter. The derrick handles light wooden slings, capable of holding 40 sacks of cement. While the scow is at the work the cement required in the mixing plant is handled by the derrick directly to the working platform at the end of the sand and stone pocket. The derrick is also used at the same time to deliver cement from the scow to cars, on which it is carried into the cement shed. When the scow is away securing more cement, the stock in the shed is used. With this arrangement much of the cement has to be handled only once, while a stock adequate to insure against emergencies is available.

The floor of the first story of the tower of the concrete mixing plant is level with the top course of timbers in the crib, and also with the floor carrying the two tracks under the sand and stone pocket. Those two tracks extend from the end of the pocket up to the third story of the tower on an incline. The second story of the tower contains the concrete mixer, and the first story tracks leading out over the crib of the cofferdam. The whole concrete mixing and handling plant is designed to handle 2½ yd. batches, and has been demonstrated to have a nominal average capacity of 100 cu. yd. per hour, with a force of 60 men, including the materials-handling crews and the concrete gangs in the cofferdam.

A hopper car divided into two steel-lined compartments, one for sand and one for stone, with a combined capacity of 2½ yd. in the two compartments, is operated on each of the two tracks extending under the sand and stone pockets. Materials will be drawn first from one side and then from the other side of the pockets to avoid trimming in the latter. The two cars are handled along the tracks and up the incline leading to the third story of the mixer tower by a double-drum Lidgerwood hoisting engine in the three-story mixer tower beyond the head of the incline. After one compartment of a car is first filled with stone from the gates in the pocket, the car is pulled ahead and the other compartment filled with sand, marks in the hoppers indicating the amount of each required. The cement is then added through an under-cut gate leading from the bottom of the working platform at the shore end of the pocket. One of these cement hoppers is placed over each track, only enough cement being stored on the platform to meet momentary fluctuations. The loaded car is hauled up the incline and dumped by means of a gate in the bottom of each hopper of the car into a hopper under the track, the empty car running back down the incline by gravity. The gates under the sand and stone pockets and the car hoppers are so arranged that a loaded car can be delivered to the mixer tower on each track fast enough to insure the capacity of the mixing plant to be maintained, in case one track is out of service.

A 2½-yd. Ransome concrete mixer, specially arranged for this contract, is mounted in the second story of the tower, where it is fed directly by the hopper under the head of the tracks on the incline. This mixer is belt-driven by a 40-h.-p. electric motor and discharges through the second floor into buckets on cars on the track below. Water is supplied to it from a measuring tank on the floor above, a quick-opening valve, operated from the floor below, controlling this tank. The gate on the track hopper supplying the mixer is also controlled from the same position, so one man feeds the mixer and attends the motor. A second man handles the balanced discharge chute of the mixer.

Two parallel standard-gauge tracks extend the length of the cofferdam, 5.5 ft. on each side of the longitudinal center line. The concrete is discharged from the mixer into 2½-yd. bottom-dump buckets on flat cars on one of these tracks. These cars are hauled out on the track by a C. W. Hunt steel-cable car-haul. The engine driving this car-haul is placed under the shore end of the sand and stone pockets. The cable extends out on the loaded-car track, around a sheave wheel at the end of that track and back on the empty-car track. Each car is equipped with a clutch which is attached to the cable when the car leaves the mixer tower. As the speed of the cable is about as fast as a man walks, a rider is not required on the car, the clutch being released by a man along the track when the car reaches the desired position.

Two gangs of concrete men are worked in the dock, one on each side of the center. Ten of the 2½-yd. bottom-dump buckets are provided, five of which are painted red and the remainder black, the red buckets serving one gang and the black ones the other. The gang for which the car is designated is thus evident and mistakes are avoided.

The buckets are handled from the cars to place by four traveling stiff-leg bull-wheel derricks, two of which travel on four rails on each side of the two cement-car tracks. These derricks are all standard sizes, their corresponding parts and castings all being duplicates. In fact, the various parts of all the derricks on the contract are made thus and the patterns for the cast parts were retained in order to facilitate repairs. Each derrick has a triangular platform carried by six pairs of traveler wheels and is operated by a double-drum Lidgerwood hoisting engine, with a bull-wheel turning drum.

General View of Toledo Water Filtration Plant, under Construction.

The various derricks and other plant around the work, except the concrete mixer and the two 15-in. centrifugal pumps, are operated on steam delivered from a central station on the shore. This station contains 300 h.-p. in boilers, and is about 350 ft. from the off-shore end of the cofferdam. A 6-in. main steam line is carried overhead from it to the longitudinal axis of the cofferdam, from which point a 4-in. branch extends the length of the dock, and a 3-in. branch extends to the sand and stone pocket. Hose couplings are placed in these branches at various points, in order that the construction equipment may be served conveniently at any part of the work. The main steam lines are all covered with wool wrapped in painted canvas to reduce the loss due to radiation. The connections at various points are made with wire-wound rubber hose. A complete system of drip pipes is provided to return the condensed water to a hot well at the station.

Under the existing conditions this method of power transmission is considered the most feasible and economical that could be provided. In the first place, it is believed to be more certain than the electrical power that is available. On the other hand, the loss by condensation in the long steam mains is relatively low, since the temperature in this locality rarely, if ever, reaches the freezing point. Moreover, a separately-fired boiler for each of the derricks would have required a number of high-priced firemen that are thus eliminated; and these boilers scattered around the large timber structures would have offered a constant fire hazard of serious moment. Steam coal is also worth $12 to $14 a ton, while fuel oil is obtained at 57 cents a barrel and can be stored in a 2,000-bbl. tank adjacent to the central station, whereas it could not be used with any degree of safety to fire boilers around the timber structures.

The central station also contains an air compressor, with a capacity of 125 cu. ft. of free air per minute, which supplies a system of pipes extending to all parts of the work. This air distribution system was used to special advantage during the construction of the crib and so forth in connection with air-driven boring machines and hammers.

A completely equipped machine shop in which all minor repairs to equipment can be made adjoins the central power station. Heavy repairs are mostly made in the adjoining shops of the navy yard, or in various private shops in San Francisco.

The plant of the Scofield Construction Co. was designed and the methods followed were devised up to the time this description was prepared with Mr. E. M. Scofield as chief engineer and Mr. Francis B. Smith as superintendent in immediate charge.

An Aerial Cableway 4.8 miles long has been used for conveying contractors' equipment, materials and supplies for the construction of the reservoir dam of a new hydro-electric plant at Loch Leven, Scotland. The ground between the loch and the dam, which is at an elevation of 1,075 ft. above the loch level, is very steep, rendering transportation by any method other than a cableway almost impossible. The mean gradient is 1 in 22.8 against the loads. There are six stations for loading and unloading, three being at the angles in the line. The single rope system is used, being supported by 86 wooden towers, of an average height of 24 ft. The longest span is about 900 ft. The power driving the ropeway is a Pelton wheel of 250 b.h.p., the speed being reduced by gearing so as to drive the rope at 300 ft. per minute. About 580 buckets, with a capacity of 600 lb. are used, and spaced about 90 ft. apart. The material handled varies from 700 to 1,000 tons per day. Twenty men are engaged in its operation; one man at the power house, three men at each of the three angle and delivery stations, four men at the upper and four at the lower terminal for handling the materials and the buckets, and two men for lubricating the pulleys on the towers. The upper terminal is a trestle 105 ft. long, 20 ft. wide, and 50 ft. high, containing bins for storing 450 to 500 tons of ballast. The total cost of the line, according to "The Engineer," London, from which these notes are taken, was £12,500, or at the rate of about £2,500 per mile. The estimated cost of operation per ton-mile, allowing for redemption in three years, labor and 10 per cent. on the labor account for supervision, is two pence.

South Half of Plant; Main Entrance at Right.

Raw Water Ducts and Arch of Passageway.

Construction Methods at the Water Purification Plant at Toledo, Ohio.

By H. McKechnie, Assistant Engineer.

The mechanical filtration plant for purifying the water supply of the city of Toledo, O., is located on the west bank of the Maumee River about a mile south of the city limits. The supply is taken from the river, the source and method of purification having been decided on after an expert commission, appointed by the city council, had investigated several methods of securing pure water. The plant is designed for a capacity of 60,000,000 gal. in 24 hours, the actual construction at the present time being for one-third this capacity, or 20,000,000 gal., the remainder of the plant to be built as needed.

The portion thus far completed comprises the main building, 51 x 237 ft. in plan, in which are located a storage room, measuring 32 x 86 ft.; laboratory, foyer and office in the center of the building, a machinery room, 32 x 42 ft.; two lime tanks, 15 x 32 ft., and two coagulant tanks, 15 x 32 ft.; an influent well and a passageway. Located over the passageway are the raw water ducts which carry the water to and from the coagulating basins. These basins are located directly back of the main building and measure 100 x 500 ft., there being two of them, one on either side of the filter house, which is located back of the center of the main building.

The water enters the influent well, in the center of the building, where it receives its first treatment of lime solution, and then rises to one of the raw water ducts and passes to the coagulating basin. As it enters this duct it is treated with a solution of sulphate of iron or alumina and again treated with the coagulant when it enters the basins. It then passes down the entire length of these basins, which are divided in the center by a baffle wall, and over a weir in the baffle wall at the far end, where the third treatment with the coagulant solution is administered. Returning along the other side of the basin, it passes over a weir or skimmer, which allows only the top 21 in. to flow out into the raw water ducts, receiving here the fourth treatment of the coagulant. It then flows directly to the filter house. Passing through the filters, it is carried into a 6 x 8-ft. passage and thence to the 6-ft. reinforced concrete conduit, which carries the water by gravity to the present pumping station, a distance of about 2¼ miles.

The lower part of the main building is to be of sandstone for a height of 17 ft., or level with the concrete walls; the balance of the building is to be of red brick, with sandstone trimmings and tile roof. At the left of the stonework are the walls of the lime and coagulant tanks; these walls are of mass concrete, 10 ft. thick at the bottom and 2 ft. at the top. These were built in about 20-ft. sections, expansion joints being left between all sections. These joints were mortised, about 1 ft. wide and 6 in. deep, the sides of which were painted with about ¼ in. of asphalt.

The work was started at these tanks. After excavating to the proper depth, which is only about 3 ft. below the surface, where a stiff clay was found, the footings were put in. The latter were 12 ft. wide and 1 ft. thick, the extra 2 ft. in width being part of the floor of the tank, it being the intention to keep the vertical joints away from the walls. These footings were not confined to the length of the section, but were put in continuously as fast as the earth was excavated. When the work was started a Smith mixer was used and placed just back of the main building on an elevated platform, and the concrete was dumped into wheel carts, which were handled to place over an elevated runway.

This method did not work satisfactorily, however, on account of the difficulty and expense in getting the materials to the mixer, and the latter was therefore lowered and a boom derrick installed, a pit being dug at the same time in front of the mixer to receive the buckets. A spur track from the Toledo, St. Louis & Western R. R. was put in and brought up to the mixer, permitting the materials to be unloaded directly from the cars to wheelbarrows on the elevated platform and thence to be dumped directly into the mixer.

The forms were built in sections to conform to the length of the wall to be built and, on the

Mixing Plant Back of the Main Building.

Laying Footings and Floor of Clear Well.

south half of the building, were made up of ⅞-in. matched lumber, vertically, with 4 x 4-in. studding placed on 2-ft. centers. On the north half of the building 2-in. plank dressed on one side, with 2 x 6-in. studding, was used. Two derricks were used in pouring the north end of the building, one taking the buckets from the mixer and placing them in a small car, which carried them about 75 or 80 ft., and the other located at the end of this run, taking up the buckets and swinging them to place. The method proved almost as fast as if a single derrick had been used.

One of the views shows the raw water ducts and the arch which run through the back of the main building and extend through the wall at either end for future enlargement of the plant. The ducts are 4 ft. 8 in. x 6 ft. 3 in. in section, the one to the right being for the supply to the basin and the one to the left for the return to the filters. In order that the water may enter the basins, which are located to the left of the picture, the floor is dropped about 3 ft. at the entrance and a passageway left under the return duct. The water enters this passage through a sluice gate controlled from above.

In constructing this portion of the work the footings were first put in, the one for the wall at the left including 5 ft. of the floor of the coagulating basin. The walls were then carried up to the springing line of the arch, where horizontal construction joints were left. The wall on the left was 3 ft. 6 in. thick, the one on the right 2 ft. 6 in. The arch was then sprung on Blaw collapsible steel centers and finished to the floor of the ducts, where construction joints were left for the walls above. The arch has a span of 11 ft., a rise of 2 ft. 6 in., and is reinforced with 1-in. twisted bars spaced 6 in. center to center. The walls of the ducts on the floor above were then poured. The top floor is 4 in. thick, reinforced with ½-in. round rods on 4-in. centers. The latter work was carried on in 25-ft. sections. Expansion joints were left in the lower walls and in the two outside walls, being painted with asphalt, as previously described. At the joints in the arch a ¼-in. steel plate, 10 in. wide, was used, one-half of it being imbedded in the section first poured, the other half left to project into the next section.

When the concreting of the main building was finished the mixing plant was removed and work started on the south coagulating basin and filter house. A new plant was set up about 250 ft. back of the main building and out of the way of all the construction work, and a spur track brought around to it. A cement shed, with a capacity of 10 to 15 cars, was built on the opposite side of the track from the mixer. A Ransome machine was used at this point.

The filter house is 70 ft. wide and 170 ft. long, contains 20 filters, the clear well, the operating floors and pipe galleries. The clear well and the pipe galleries were carried down about 7 ft. below ground level, necessitating an excavation 24 x 174 ft. in plan and 7 ft. deep. In making this excavation the contractor used a trenching machine which was built on the ground, and operated a Page self-loading bucket. It was mounted on a turntable, which in turn was carried on rollers, so that it could swing in a complete circle and deposit the dirt to one side of the trench, and also be moved along as fast as the work progressed. This worked very satisfactorily in the center of the trench, but, on account of the width of the latter, did not do very well on the sides, and the latter portions were therefore excavated by hand labor and teams. The earth encountered was a hard yellow clay, which made it necessary to place heavy cutting teeth on the bucket to secure the proper penetration.

In placing the concrete for this part of the work the footings of the walls and the floors of the clear well and pipe galleries were poured at one time. The reinforcement consists of ⅜-in. round rods on 12-in. centers each way. The latter were placed, thoroughly wired together, and a thin layer of concrete spread over the steel, which was then raised up into the concrete by means of hooks. In carrying out this portion of the work considerable trouble was encountered, on account of the softening of the ground, due to the wet weather. This made it necessary in some places to remove 4 to 6 in. of material below sub-grade and refill with lean concrete. In delivering concrete Koppel self-dumping cars were used, a track being laid from the mixer along one bank of the trench, and a movable chute so rigged that the concrete was deposited near the center. The footings and floors were completed in a little less than two days with a force of about 24 men, a rate considered very good under the existing conditions.

While the work just mentioned was under way construction was also being carried on in one of the large coagulating basins. The excavation for this was done by teams to within a few inches of the sub-grade, after which it was finished to an inch above that grade by hand and thoroughly rolled with a steam roller. The bases for the columns and the footings for the walls were naturally laid first, being put in as fast as the grading was completed. The column bases were 10 ft. square and 8 in. thick at the center, sloping to 6 in. at the side, on a curve with a radius of 16 ft. In shaping the surface screeds were made and fastened to the runners on all four sides and a straight edge used to form the concrete. As soon as the latter was sufficiently set the forms were removed and ¼-in. steel plates, 10 ft. long, were placed all around the bases and along the edge of the footings and the floor poured. Then when the concrete was thoroughly set the plates were taken out and the opening filled with asphalt. The plates were coated with grease so as to allow them to be easily removed.

In constructing the upper floors of the filter house and the roof and walls of the coagulating basins two Ransome mixers were placed in a pit so that they could be fed directly from the ground level, the stone and sand being brought from the mixers in patent dump cars. The mixers were operated by electric motors. A hoist was built between them to elevate the concrete to the required height, and it was then delivered to the work by the small dump cars operated over an elevated track to the wall or floor to be poured. The roof of the coagulating basin is 7 in. thick and reinforced on the Turner system. The basins when finished are to be covered with 2 ft. of earth, this covering sloping away at the sides with a 1:2 slope, leaving a 6-ft. berm at the top. This earth fill is also carried around the sides of the main building to the stonework, where it is retained by a wing wall.

In constructing the clear water conduit considerable difficulty was encountered. The conduit is of reinforced concrete, 6 ft. inside diameter, with 10-in. walls. Work was started under the main building, the first 7 ft. of excavation being done by teams. A hoisting engine was placed at one end of the trench and used for operating a plow by means of a long cable and also for hauling the wheel scrapers out of the trench. The balance of the trench was finished by hand labor and derricks. The material encountered was a layer of hard yellow clay for the first 7 or 8 ft., and below this a blue clay which was very treacherous, as it was filled with thin streams of fine yellow sand. Chunks of clay from 1 to 4 ft. square and 6 to 12 in. thick would fall from the sides and even slide out from under the skeleton sheeting, and the pockets and veins of sand brought water into the trench, making it necessary to keep a small siphon going most of the time. Outside of the limits of the building the trenching machine was used to excavate the first 8 to 10 ft. of material, the balance being taken out by hand and elevated by derricks. One of the illustrations

Trenching Machine and Derrick on Conduit Trench.

Casting the Column Bases in the Coagulating Basin.

shows this trench under construction and at the right the piles of material thrown up by the trenching machine.

When the invert in the trench had been shaped to the outer form of the concrete a 6-in. vitrified pipe was laid in a small trench at the bottom, with open joints, and covered with crushed stone, in order to carry off the surplus water during construction. A layer of concrete about 4 in. thick was then placed on the bottom and part way up the sides, the concrete being mixed fairly dry and thoroughly tamped. A Smith mixer was placed on the bank of the trench and a runway built over the work, so that the concrete could be dumped from the mixer into wheelbarrows and readily carried to place. As soon as the reinforcement was placed another lift of concrete was put in and carried up nearly to the horizontal diameter. Specially prepared tile made to conform to the curve of the arch were then imbedded in a 2-in. layer of 1:2 mortar. Blaw collapsible steel centers were used, and the conduit built in 25-ft. sections, expansion joints being left in each section and painted with asphalt when the adjoining section was placed.

The New Capitol of South Dakota.

Previous to starting the work a complete workshop was installed. It was housed in a building 40 x 120 ft., one end of which was fitted up as a carpenter shop and the other as a machine and blacksmith shop. The saws, lathes and other machinery were operated by a 15-hp. electric motor. A water tank located on top of the building supplied water for all parts of the work. The supply was brought by gravity from the canal, which runs through the back of the grounds, and flowed to a well in front of the shop, whence it was pumped to the tank.

The work is being done under the direction of the Filtration Department of the Board of Public Service of Toledo, of which Mr. Frank I. Consaul is chief engineer, and Mr. G. A. Gessner, department engineer, the writer being assistant engineer. All the work is being done by the A. Bentley & Sons Co., of Toledo, sub-contractors under the Norwood Engineering Co., who have the contract for the plant.

HYDRAULIC SLUICING is being used by the Redding, Cal. Water Co. in building a dam 30 ft. high containing 13,000 cu. yd. A giant with a 2-in. nozzle and operated by a 30-h.p. electric motor washes the dirt down the sides of the gulch into the dam, which crosses it. The cost is about 12 cents a yard.

Foundation Construction for the New State Capitol of South Dakota.

By Samuel H. Lea, M. Am. Soc. C. E., State Engineer of South Dakota.

The State of South Dakota, since its admission into the Union in 1889, has made use of a temporary frame building for a capitol. Not until the capitol of South Dakota was finally located at Pierre by popular vote in 1904 was any provision made for erecting a permanent capitol building. The state legislature of 1905 enacted a law providing for such a building, and this was amended by the legislature of 1907 into the law under which the capitol is now being constructed.

Under the provisions of the law a board, known as the State Capitol Commission, was created, with authority to erect a building on the capitol grounds at Pierre. This board consists of four members, composed of the Governor, Secretary of State, State Auditor and the Commissioner of School and Public Lands. The Governor is ex-officio chairman of the board, all the members of which serve without compensation. The sum of $600,000 was appropriated for the erection and completion of the building.

The plans and specifications for the building were prepared and adopted in 1905 and some work was done on the footings and basement walls of the east wing in that year, but work on the building as a whole was not begun until the summer of 1907, when a contract for the complete structure was awarded by the Commission to O. H. Olsen of Stillwater, Minn. The writer was appointed supervising engineer and was placed in full charge of the construction of the building.

The first work to be done was to determine the bearing power of the soil at the building site and from the information obtained, design suitable footings for the walls and columns of the building. The architect's plans called for footings of ample size and strength for ordinary ground; but the local conditions affecting foundations for heavy buildings require more than ordinary attention in this locality. The soil formation at Pierre consists of several varieties of material which may be described at follows:

1, Gumbo or ordinary earth.—This material, which composes the surface of most of the surrounding country, is a species of decomposed shale, forming a clay, grayish in color and made up of very minute particles. When dry and pulverized it forms a dust which, being very light, is blown about in stifling clouds by the wind. This material absorbs water quickly and when thoroughly wet, forms a thick tenacious mud. In its natural or normal condition, a few feet below the surface, it is quite hard and firm and capable of supporting a considerable load. When uncovered and exposed to the weather for any length of time, however, the top or exposed portion disintegrates and becomes loose and without consistency or capacity for supporting heavy burdens. It is especially affected by rain and forms quickly into a surface coating of mud resembling paste which, upon removal leaves a damp and soft sub-surface.

2, Shale.—This material, which is known to geologists as Pierre shale, is a hard, bluish substance, which is quite tough and often requires blasting to remove from its natural bed. Upon exposure to the weather, however, it soon disintegrates and in course of time forms gumbo or clay. When a solid mass of this material is encountered, a good foundation can be had by excavating several feet into the original formation. The piers for the new steel railroad bridge of the Chicago & Northwestern Ry. across the Missouri River at Pierre, have their foundations in this shale.

3, Gravel.—In many places around Pierre beds or deposits of gravel occur, of various sizes. These gravel beds are found in isolated localities and furnish sources of supply for local building needs. They are not of sufficient extent, however, to constitute a large factor in the foundation situation.

The experience obtained from buildings that have been erected in Pierre is such as to warrant the observance of caution in erecting structures of magnitude. Among the older buildings in the city is the Court House, a brick structure which, according to the inscription over its front entrance, was erected in 1883. This building shows evidences of settlement to an alarming degree. Large cracks appear in its walls and these are now held together by massive iron rods running entirely through the building. The floor near the center, where supported by partition walls, is much higher than on the sides near the outer walls. Altogether this structure presents a decidely "settled" appearance.

Many of the larger brick buildings which were erected during the "boom" days about twenty-five years ago, show in their walls cracks of more or less size and extent that are undoubtedly due to unequal settlement. While it is true that many of these buildings were hastily erected, without proper precautions being taken for securing good foundations, it is probable that some of them were carefully built with what were considered to be suitable footings.

Several structures of considerable magnitude have been erected in Pierre in the last few years. Of these the most important is the public building erected by the U. S. Government for a post office and for court rooms, land office and other public uses. This is a massive structure, of the type common to government buildings of this class. It is of Bedford, Ind., stone, with granite base, and is provided with footings of the usual dimensions for such a building, and of ample size for foundations in ordinary material. The site of this structure is on sloping ground, the rear portion of the site being several feet higher than the street level in front. Upon being excavated to the foundation level a bed of shale was disclosed, covering only a portion of the building site. The building rested partly on this shale and partly on the clay or gumbo immediately adjacent thereto. The result of this variation in the supporting material was an ugly settlement crack which appeared through the wall and roof of the building shortly after its completion.

Other large buildings of recent construction in this locality have shown evidences of unequal settlement of more or less extent. In one instance the basement wall of a large new structure sank 4 in. at one corner before the superstructure was begun.

These and other similar experiences in heavy building construction at Pierre were not reassuring to those contemplating work of this character. They served to emphasize the necessity for careful work in preparing the foundations for such a massive structure as the proposed state capitol. It was evident that the nature of the soil at the building site would have to be ascertained in order to determine its bearing capacity and also to decide upon the most suitable method for making the footings stable and secure.

The site of the capitol is on high ground overlooking the Missouri River and the valley of the Teton River, a tributary on its west bank. The soil formation is gumbo with occasional thin streaks of gravel occurring at irregular intervals a few feet below the surface. The depth of excavation for footings, as required by the architect's plan, was from 6 to 8 ft., and as this depth was found to afford as good a quality of material as could be obtained by deeper excavation, it was adhered to throughout.

The maximum load on the wall footings was found by computation to be 1½ tons per square foot, and it was thought that the natural formation, if properly cared for, would carry this load satisfactorily. In making the excavation it was found that the soil was hard and firm a few feet below the surface and that it remained unchanged to whatever depth penetrated.

In order to determine accurately its bearing capacity, test pits were excavated to the depth required for footings at a number of places on the building site. At the bottom of each pit a bearing surface was prepared under the personal supervision of the writer, great care being taken to dress and scrape it to a smooth horizontal surface which was tested with a machinist's level. Upon this prepared surface rested the foot of a testing apparatus designed for this purpose. This apparatus consisted of a 12 x 12-in. post, 6 ft. long, whose ends were cut exactly square and smooth, at the upper end of which was secured a horizontal platform 6 ft. square. This platform was braced to the vertical post in the manner shown in Fig. 1. The foot of the apparatus was seated accurately with an even bearing and uniform contact with the surface of the ground at each point where a test was made. Before loading, levels were carefully taken to ascertain the height of the platform and when the load was applied observations were made to determine the exact moment when settling began, the load required to cause settlement and the depth of same. The platform was loaded with cement in sacks, this material being the most convenient for use in the tests. A load of 3 tons was placed on the platform when a settlement of 3/16 in. was noted. The loaded platform was allowed to remain in position over night but no further settlement took place. A number of tests were made with practically the same results in each case, and it was decided that the bearing capacity of the soil was amply sufficient for the load to be carried.

In excavating the trenches for the footings the soil was carefully examined to ascertain if there were any soft spots requiring special attention. In some cases it was found that the material was not quite so hard and solid as the general formation, but these were in isolated spots or streaks of small extent. In order, however, to provide against any tendency to unequal settlement that might be due to the softening of the ground under the footings, it was decided to make the footings continuous throughout the outer walls, and to reinforce them with steel bars.

The footings were made of concrete composed of Portland cement, sand and gravel in the proportions of 1:3:5. The concrete was mixed wet, and the footings were built with sloping sides instead of in steps, the sloping form being considered preferable. The footings were built as nearly monolithic as possible and were reinforced near the bottom with ¾-in. steel bars, spaced 8 in. apart, both longitudinally and transversely over the entire area covered by the footings. This formed a steel grillage which serves to bind the footing together throughout its entire length and thus overcome any tendency to unequal settlement.

The basement walls of the East wing, which were built about 3 years ago, were carefully examined for signs of deterioration or weakness, and test pits were dug at several places along these walls to disclose the character of the soil under the old footings. At one place, near where the old work joins the new, there was found a crack of considerable extent in the old wall, which, upon examination, was decided to have been caused by settlement. A section of the old wall enclosing this crack was taken down and it was found, upon examination, that the ground under the footing at this point had become saturated with water, which caused the soil to soften, resulting in the settlement of the old wall immediately above. The soft ground was removed, and a wider footing, reinforced and connecting with the adjacent new footing, was made; the wall was then rebuilt.

This occurrence indicated that the probable cause of settlement in some of the other buildings in Pierre, of which mention has been made, was water getting underneath the footings and causing the soil to compress. In order to avoid any danger from this source the writer provided a method for intercepting outside or surface water and prevent it from reaching the ground under the footings. This consisted in laying a line of 4-in. porous tile around the building outside the wall footing and adjacent thereto, as shown in Fig. 2. The tiling was laid on a cement base and was given a fall from a high point to an outlet provided for the purpose. The joints were covered with tar paper and a covering of several inches of gravel was placed over the drain before the earth was filled in against the footing and wall. By means of the care that has been exercised and the precautions that have been taken in constructing the foundations, as above described, it is believed that danger from unequal settlement has been practically eliminated.

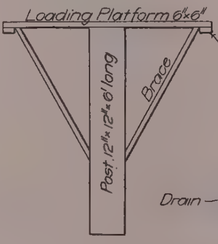


Fig. 1

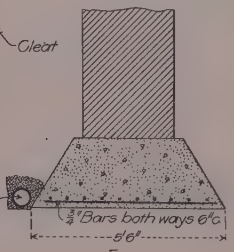


Fig. 2

A 60,000-Volt Transmission Line has recently been placed in service to bring energy from a hydro-electric station on the Ugigawa River to Tokio, a distance of 25 miles. The station contains six 3,000-kw. generators furnishing 50-cycle, 6,500-volt current. This is stepped up by water-cooled transformers to 60,000 volts at which protential it is transmitted to a sub-station just outside the city. Here there are water-cooled transformers which reduce the line potential to 11,000 volts, at which it is transmitted underground through lead-armored cables to 11 distributing stations in various parts of the city. In each of these smaller stations there are oil-cooled transformers reducing the voltage to 2,000 volts. The entire transformer, regulating and controlling equipment, with the lead-armored cables, has been supplied by the General Electric Co.

Connecting the Detroit River Tunnel Tubes.

The subaqueous section of the double-track Detroit River tunnel is about 2622 ft. long and has two parallel steel tubes 23 ft. 4 in. in diameter lined with concrete and enclosed in a mass of concrete about 56 ft. wide and 31 ft. high deposited in an open trench dredged in the bottom of the river, as described in The Engineering Record of March 2, 1907.

The steel tubes are built on shore in lengths of about 262 ft., launched, towed to position, sunk under control by an ingenious system of air chambers, connected in position by divers, and finally concreted as described in The Engineering Record of Nov. 9, 1907. The magnitude of the work, the novel method of executing it, the varying details of construction and adjustment of the 800-ton tube sections, and their manipulation in deep water, are of unusual interest, and the following statement just received from the engineering member of the contracting company shows that the most critical and delicate part of the undertaking has been successfully accomplished and that a satisfactory completion of the work may be confidently expected.

The rear end of each section of the tube is slightly enlarged to receive the forward end of the next section, and the annular space about 4 in. wide and 15 in. long between the two shells at this joint is closed by a rubber gasket bolted between flange angles and filled with cement grout. In order to facilitate the entrance of one tube into the sleeve of the adjacent tube, four steel castings are riveted to the exterior of each, close to the end in the same radial plane, and are bored for 6-in. horizontal pilot pins 5 in. in diameter parallel to the axis of the tubes. These pins are set in the sleeve castings, projecting about 40 in. beyond the ends of the sleeves; steel cables are attached to their tapered outer ends and, passing through the conical holes in the opposite castings, are led around sheaves at the rear ends of the tubes already in position and up to winches on the operating scow. The suspended tubes are provided with preventer tackles and as they sink into position the latter are overhauled and the pilot pin cables are wound up, thus insuring the engagement of the pilot pins with the tapered holes and permitting the tubes to be drawn longitudinally into their required position. Afterwards the joints are locked by wedges driven by drivers through slots in the pilot pins.

The first tube of the suabqueous section was sunk Oct. 1, 1907, and the second one on Nov. 25, 1907, and the connection between them was completed within a few days. Mr. Olaf Hoff, of Butler Bros.-Hoff Co., New York, states in a letter of March 13, 1908: "This connection was made fully as easily as was expected, everything working out very satisfactorily, and we received a very eulogistic letter from the chief engineer on the occasion. The pilot pins worked like a charm, guiding the second section into its proper place, and the bolt holes through the flanges of the two sections, with the rubber gasket between, came so true that the diver had no difficulty whatever in inserting the bolts and thus connecting up. One diver did this work in two days. The bottom of the second tube was then concreted and six of the pockets were filled with concrete to the top before the winter set in, preventing further operations in the river."

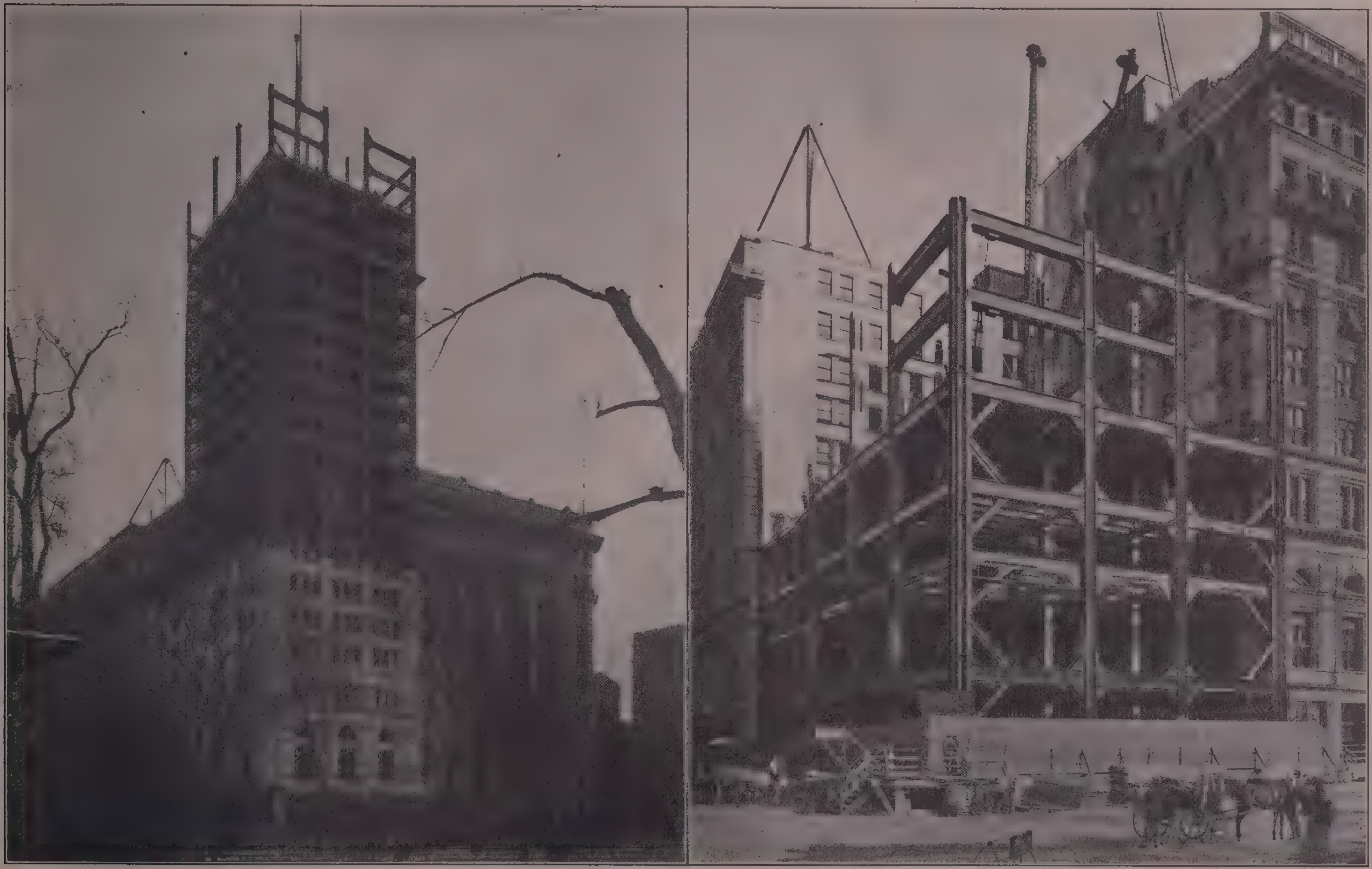
Two more sections of the tube are launched and are ready to sink and the fifth section is now on the ways, very nearly ready for launching. As soon as the ice leaves the river dredging will be resumed, concreting will be commenced and preparations made for sinking the sections.

Although the heavy ice necessitated the suspension of dredging and concreting on the subaqueous portion during the winter, preparatory work was in progress for this section of the tunnel and construction was maintained on the approach tunnels on both sides of the river. A new scow 121 ft. long, 31 ft. wide and 8 ft. 4 in. deep was built and equipped with derricks, shear legs, spuds and other accessories, for use in setting the buoyancy cylinders on the tubes before sinking, for setting grillages and for sinking tubes and connecting them up, so that the scow previously used for these purposes and for concreting can be devoted exclusively to the preparation and deposition of concrete around the tubes after they are sunk.

Satisfactory progress is being made on the American approach, where a progress of 7 to 8 ft. a day is made with the tunnel shield, and the open cut is so far advanced that its completion during the summer is assured. On the Canadian approach the inflow of clay has made the shield work very difficult and produced an extraordinary settlement of ground overhead. In consequence a compressed air plant has been installed and operations have just been commenced with it, which it is expected will overcome all difficulties there. The open cut on this side of the river is progressing satisfactorily and will also be completed during the present summer. The tunnel is being built by the Detroit River Tunnel Co., Mr. W. S. Kinnear, chief engineer, in accordance with plans originally prepared by Mr. W. J. Wilgus and modified in some details by the contractors.

An Old French Dredge of the ladder type which was found lying near Cristobal by the Isthmian Canal Commission was repaired several years ago, under the direction of Mr. F. B. Maltby, and used for about a year. More recently the hull was repaired and a new boiler put in, with the result that for a total expense of about $25,000 a good dredge, with a monthly capacity of about 125,000 cu. yd., has been put in service. This is the third French ladder dredge to be put in operation.

THE ERECTION OF THE METROPOLITAN LIFE BUILDING TOWER, NEW YORK.



Two Views of the Tower of the Metropolitan Life Insurance Building at New York.

The Home Office Building of the Metropolitan Life Insurance Co., which is now nearing completion, is, with reference to the area of ground occupied, one of the largest of large office buildings and has been under construction since May, 1890, successive sections, forming integral parts of a harmonious whole, having been added from time to time as the needs of the company demanded and as additional space could be secured until the completed structure now has extreme dimensions of about 200 x 425 ft. and occupies the entire large block included between 23d and 24th Sts. and Madison and Fourth Aves.; its moderate height of 11 stories, or about 161 ft., for the main part, together with the carefully detailed early Italian renaissance design, gives it dignity and beauty which are enhanced by its commanding position facing Madison Sq., and the final addition at one corner of a massive tower gives it a very imposing and striking appearance under conditions where the magnitude and architectural effect can be well appreciated.

The lower part of the tower is continuous with the main building and conforms to it in architectural treatment which is such that the entire mass of the main building serves as an enriched base for its great shaft extending 37 stories, or over 500 ft., above it to a total height of 683 ft. above the curb, an altitude equalled by no other structure except the Eiffel Tower, Paris, which, of course, being only an observation skeleton, is not comparable with this fireproof building intended for constant occupancy for business purposes.

Structurally considered this tower is a large 48-story rectangular building with ample street fronts of 75 ft. and 85 ft. and is independent of the 11-story main building with which its exterior walls are continuous. The walls are entirely of white marble backed with brick and supported on steel girders at every floor and the floors are of Roebling concrete segmental arch construction. At a height of 393 ft. above the curb the tower is enclosed by a three-story loggia with an ornamental colonnade and a heavy projecting cornice underneath. Above the loggia the dimensions of the tower are reduced to 58 x 64 ft. up to a total height of 491½ ft. above the curb where the tiled pyramidal roof begins and rises 100 ft. to the 18 x 18-ft. 45th floor, above which it has vertical walls about 67 ft. high to the commencement of the lantern roof which terminates 683 ft. above the curb.

Up to the 31st floor there are 20 columns, 12 of which are in the planes of the wall and extend to the level of the 35th floor. From the 35th to the 39th floor there are 16 interior columns besides the 12 exterior columns continued for the loggia construction and from the 35th to the 39th floor there are 16 columns. Above the 39th floor the number of columns diminishes with the convergence of the roof. The tower is proportioned for a wind pressure of 30 lb. per square foot over the entire exposed surface and these stresses, together with the heavy walls, live loads and great height of the structure being up the maximum stresses in the corner columns to the almost or quite unprecedented amounts of 7,500,000 lb. each.

These are provided for with cross-sectional areas of about 540 sq. in., which with the details bring the weights of the columns up to about 1 ton per lineal foot. The lower stories of the columns have a special cross-section like a square with each side produced a little beyond the angle and are made up with four 8 x 8-in. flange angles and 20 full-length web and flange plates 1 in. thick and from 8 to 20 in. wide. The base plates are 38 in. square and the splices 2½ ft. above every second floor are made with horizontal diaphragms and vertical cover plates. The intermediate columns are made with closed rectangular cross-sections built up with plates and angles and having center webs.

Four of the interior columns terminate at the 31st floor, where they are connected by pairs of plate girders with the 34th story wall columns, which support between them the offset wall columns in the 35th story and above. The wall columns which terminate at the 35th floor are connected at that level and at the 34th floor by plate girders carrying the masonry of the loggia walls and are very rigidly X-braced the full depth of the 34th story, thus making a sort of false truss, which differs from a true truss in that the diagonal members do not intersect in the chords where there is considerable space between their extremities, thus developing a bending moment in the wall girders.

Every story below the 39th has a wind system of deep solid web wall girders and heavy channel iron knee braces down to the 12th floor. Below the 12th floor the wall girders are made double in each panel and their column connections are very deep gusset plates, integral with their webs so that great rigidity is developed in the framework. The floor beams and girders are of the ordinary type with standard connections, as shown in The Engineering Record of Feb. 9 and July 13, 1907. Great care was exercised in the fabrication of the steel work, all holes being drilled from the solid metal without sub-punching. The members are painted with "Tockolith" finished with No. 112 R. I. W. above ground and waterproof No. 110 R. I. W. below ground.

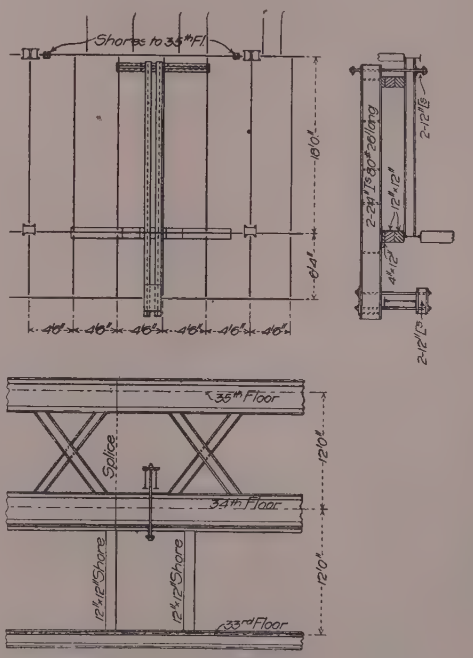
The wall columns are seated on annealed cast-steel pedestals, 7 ft. square, which weigh about 12 tons each. Excavation was made to solid rock at an average depth of about 30 ft. below the curb and the bottoms of the pits were leveled and covered with a thin layer of concrete in which were formed pairs of transverse screeds about 1 in. high with their upper surfaces very accurately finished in the required horizontal planes of the grillage beam flanges. On them were set the lower tiers of 24-in. I-beams, which with the one, two or even three tiers of crossed upper beams, were concreted and formed the bases on which the cast-steel pedestals were set by a steel derrick with a 90-ft. mast and 75-ft. 30-ton boom guyed with eight 1⅜-in. steel ropes.

This derrick was located nearly in the center of the tower and commanded its whole area with sufficient boom radius to reach beyond it and unload material from trucks in the street. After erecting the pedestals, columns and the first two tiers of beams, the derrick was lifted in the usual way and reseated on the upper tier, then erected two more tiers and was moved again and so on, being out of service only about 3½ hours at each removal. This derrick fully rigged weighed about 14 tons and with its maximum loads imposed a greater weight than it was considered safe to concentrate on the floor beams of the tower and a group of four 24-in. I-beams about 25 ft. long was used to form a sill on which the foot block was seated and which served to transfer the reactions to the main interior columns of the tower.

The heaviest members handled by the derrick were the 30-ton, 40-ft., second and third-story sections of the wall columns, which were well within its capacity. The wall columns adjacent to the existing building are recessed 4 in. into the wall of the latter with clearance so small that there was no room to handle them with ordinary hoisting clamps. Special attachments were therefore made about 6 ft. below the upper end with 1-in. steel rope having six round turns about the column and bearing on wooden friction pieces. The ends of a heavy bridle chain were shackled to five strands of the cable on opposite sides of the column, the bight of the chain, beyond the top of the column, was hooked to the lower tackle block and the column was easily hoisted, the cramping of the rope, the friction of the wooden fillers and the resistance of the rivet heads effectually preventing any slipping of the connection.

Above the fourth floor the columns were lighter and were lifted by pairs of bridles secured to the open holes left for the field rivets in the splices. A 6 x 6 x ¾-in. vertical angle about 3 ft. long was bolted on each corner of the column with the upper end projecting about a foot beyond the column. The shackles were connected by 1½-in. pins to the upper ends of these angles and the ¾-in. steel cables to which they were secured formed the bridles engaging the tackle. This connection proved very simple and efficient and was conveniently and quickly adjusted

The verticality of the columns was checked with a special plumb bob made from a 16-in. length of steam pipe 6 in. in diameter with a solid conical steel point screwed in at the lower end and a perforated cap screwed on top. The pipe was loaded with 100 lb. of bird shot and was suspended by a steel cable 3/16 in. in diameter wound on a small hand windlass with an angle iron frame bolted to the columns or girders so as to offset the plumb line about 4 ft. beyond the face of the steelwork. With this apparatus each of the four corner columns and the four elevator columns were carefully plumbed at every second story and were maintained throughout the erection with a deviation not exceeding 3/16 in. from the true vertical.



Cantilever Supports used in Erecting the Tower.

At the commencement of erection six steel cables, ⅞ in. in diameter, were cut to the required length and fitted with a shackle at the lower end and a hook forged from a thick flat steel plate and fitted to engage the top flange of a wall girder attached to the opposite end, the center being adjustable by a turn-buckle about 6 ft. long. Pairs of these diagonals were put as needed in the panels between wall columns and girders in the upper four stories and were adjusted to stiffen the support for the derrick and maintain the verticality of the columns until the connections were riveted, shifting the lower set to the top as the work advanced. The guys reached the full length of the columns, taking in two stories or two panels of the framework, so that eight sufficed for one complete set, thus leaving two extra ones to use for special purposes.

The lengths of the columns vary from 16 ft. to 29 ft. and the weight from 3½ tons to 30 tons each, with a corresponding dimunition of cross-section from 44 x 44 in. to 12 x 12 in. The wind-brace girders weigh from 5 to 10 tons each and where they are double the clearance between them is so small that some of the connection rivets could not be driven and were necessarily replaced by bolts. Many of the girder and knee-brace connections to the wall columns are made with pairs of very heavy vertical angles, 7 ft. or more in length, with their outstanding flanges so wide and so close together that it was exceedingly difficult to enter the webs of the girders and knee braces and in some cases the latter had to be hoisted to the story above and lowered the full length of the column and were even then forced between the jaws with great difficulty by the use of steamboat ratchets. Otherwise the connections were easily made, the different members fitted well and the shopwork was considered excellent and accurate.

In the 31st floor there are a number of plate girders carrying the upper set of interior columns, some of them are 48 in. deep, 25 ft. long and weigh 10 tons each, but were erected without difficulty at a height of 393 ft. above the curb. Both the 30th and the 31st floors are heavier than the regular tower construction and the two tiers weigh together 472 tons. The 28th and 29th tiers together weigh 376 tons. The weight of the members decreases in the upper part of the tower and it was so much diminished that at the 33d story the 30-ton derrick above described was replaced by one of similar construction, having a 65-ft. boom of 12 tons capacity, weighing about eight tons, that is competent for the remaining service and enabled the heavier derrick to be transferred to other work. Both derricks were operated by a gang of nine men, who have made on this job the maximum record of 130 tons erected in eight hours, and two stories, weighing together 350 tons, erected in eight working days.

Special provision was made for the erection of the false trusses in the 34th story, which connect the tops of the outer wall columns. Two of these trusses are 70 ft. and two are 84 ft. long, weighing about 22 tons and 26 tons each, respectively. They all have a uniform depth of 15 ft. overall and their top and bottom chords are made with plate girders 40 in. deep with a maximum weight of 12 tons each.

Pairs of 24-in., 80-lb. I-beams, 26 ft. long, which had previously been used for derrick sills, were bolted together to make eight horizontal outriggers for the support of these trusses during their erection. Each pair of I-beams was blocked up a little more than 2 ft. from the top flanges of the 34th tier floor beams and girders in the tower framework inclosed by the loggia. They were set perpendicular to the face of the tower with the outer ends projecting 8 to 10 ft. beyond the centers of the inner wall columns and 1 ft. 9 in. beyond the center lines of the trusses. They were fulcrumed on the wall girders and anchored at the inner ends by three 1½-in. vertical rods about 8 ft. long with screw ends. At both ends the rods had nuts engaging bearing plates on the flanges of reaction girders composed of pairs of 12-in. channels back to back.

The upper channels were only 3 ft. long and were seated on the top flanges of the cantilever beams. The bottom channels, from 7 to 10 ft. long, took bearing against the bottom flanges of the floor beams and girders to which they were connected by bolts for which special holes were drilled to eliminate all danger of displacement. The anchor rods were screwed up tight against wooden fillers between the ends of the cantilever beams and the floor girders and after the outriggers were adjusted in position the bottom chord sections suspended from the derrick booms were swung under their cantilever projections and were attached to the latter by pairs of screw-end 1½-in. vertical rods with their upper nuts engaging fixed bearing plates on the top flanges of the I-beams and the lower nuts engaging short transverse girders made with pairs of 12-in. channels 2½ ft. long transverse to the bottom flange of the lower chord section and thus forming with the vertical rods adjustable yokes supporting the lower chords after the derrick tackles were disconnected.

A 12 x 12-in. vertical shore, about 10 ft. long, was seated on the 33d story wall girder, each side of the cantilever out-rigger and wedged against the bottom flange of the lower chord section to give additional security. The chord sections were set 1 in. high and spliced together and the web members of the truss, received in pairs shop riveted together making Xs, were assembled to them and the top chord sections placed on them completing the trusses which were temporarily secured by ties and braces to the interior framework of the tower. The trusses were cambered for final connection by screwing up the suspension rods at the ends of the outriggers and following up by wedging the shores, and the outriggers were not removed until the trusses were completely riveted to the columns.

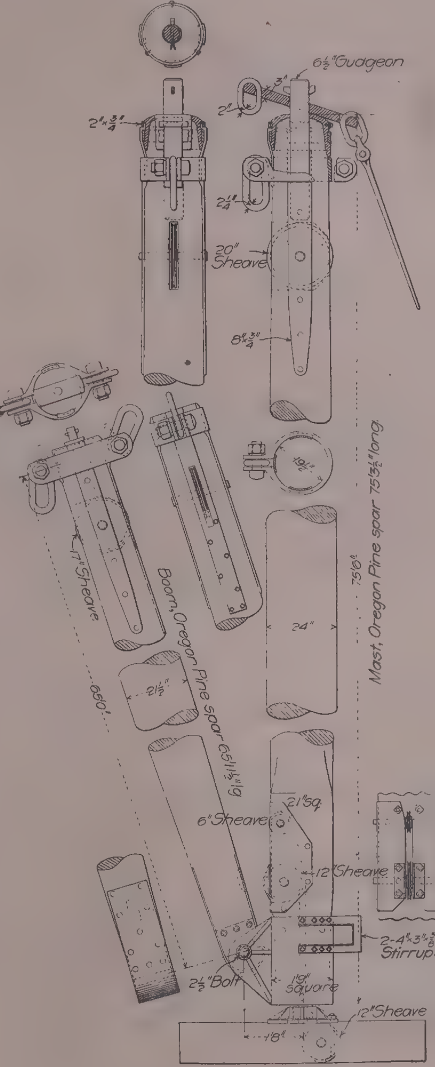
Above the 35th floor the heaviest pieces to be handled will be the 48-in. plate girders, 22 ft. long, weighing 4½ tons each, in the 39th floor at an elevation of about 491 ft. above the curb. These will be erected with the 12-ton guyed derrick now in service, which can set the members of the pyramidal roof up to and including the 41st floor, above which all the members will be handled by a gin-pole and jinnywink, easily lifted from tier to tier, which will receive the members from the guyed derrick, which will hoist them from the street. The heaviest members thus handled will be the 36-in. plate girders, 23 ft. long, weighing 2¾ tons each, in the 44th floor and a 42-in., 19-ft., 2-ton plate girder in the 45th floor, above which no single member will have a weight of more than 1,500 lb.

All hoisting has been done with a special 50-h.-p. Lidgerwood engine permanently located on the ground floor of the tower. The drums are of extra length to accommodate the 2,500 ft. of ¾-in. fall line and the 1,200 ft. of ⅞-in. topping line wound on them with a maximum of five layers. The entire length of line required to reeve the hoisting tackle is 2,700 ft. All materials are hoisted from trucks in 24th St. with the boom at long radius to swing them 22 ft. beyond the face of the tower and clear a falsework platform projecting 15 ft. beyond the outer wall at the 17th story, which was built by the general contractor to provide storage and working space for the masons and to serve as an additional protection for the street below.

This platform intercepts such a wide angle of vision from the top of the tower that it is impossible to see any portion of 24th St. below it and the unloading cannot therefore be directed from the top of the tower. Whenever it is necessary to communicate between the tower and the trucks in the street a man is stationed for that purpose in Madison Ave., north of 24th St., where he can signal to both parties. The boom is swung by side lines led to capstan heads on the hoisting engine. The hoisting has been done at a speed requiring not more than 3½ minutes ordinarily to raise a piece of any weight from the street to a height of 500 ft. Notwithstanding the height, speed and the swaying of the load, many of the erectors preferred to ride the tackle blocks up and down rather than take the stairs or elevator, a practice which has been rigidly discouraged by the superintendent.

The hoisting engine is located in a small wooden shed inside the main building, and is thus doubly deprived of all possibility of seeing the materials hoisted. It is operated entirely by three signals bells governing the two main drums and the swinging gear. A stand, sheltered by a heavy canvas screen, is maintained on the highest working tier and moved up as the erection progresses, and to it are led three vertical lines of heavy braided cord connected to the signal bell. Owing to their great length these are so heavy that they have to be provided with a 2-part tackle to be conveniently operated. A telephone is also maintained at the signal stand and provides constant communication with the superintendent's office on the 1st floor, where there is a long distance telephone with city connections. The bells are also connected to operating lines accessible from the street where the trucks are unloaded.

A Clayton air compressor is installed on the 1st floor of the tower near the hoisting engine and delivers through a vertical riser pipe with outlets at every successive story for flexible connections to which seven Cleveland pneumatic hammers and one reaming tool are attached. The riveting follows the erection as closely as possible and is usually not more than three tiers below it. The construction of the concrete reinforced floor arches is maintained about four floors below the erecting, and the outer walls are at this time about fifteen floors below the steel work.



Fittings of Derrick.

The heavy cross sections, deep joints and knee-brace systems have proved so efficient that the tower has so far developed great rigidity and has not shown appreciable vibration even during the severest winds which have made the erection difficult and dangerous, as can be judged by the fact that it has often been necessary to add a second tackle to the boom to swing it when the wind was blowing harder than usual.

Great care has been taken to observe all safety precautions, to maintain the working platform in the best possible condition and to avoid dropping any tools or material from the upper part of the tower. So far no serious accident of any sort has occurred and the work is progressing like that of an ordinary steel building. The machinery for two of the permanent elevators in the tower has been installed early in the progress of the erection, and as the guides are extended with the progress of the work, the elevator runs constantly to within a few stories of the derrick, and is a very important factor in saving time and labor by carrying the men up and down to and from their work. The erection of the tower was commenced May, 1907, and has been carried on continuously, with very little delay on account of bad weather or for materials, by an average force of 60 men. The steel work was erected up to the 37th floor April 1, and it is expected that it will be completed in May. In addition to the tower construction the same contractors are erecting a 60 x 75-ft. 11-story extension to the main building. This is of ordinary construction and the 550 tons of steel are handled by a stiffleg derrick located on the roof of the finished portion of the building.

Messrs. N. LeBrun & Sons are the architects. and the Hedden Construction Co. is the general contractor, Mr. J. B. Cleremont, superintendent. Purdy & Henderson are the consulting engineers, and the structural steel work was fabricated at the Ambridge plant of the American Bridge Co., and is erected by Post & McCord; Mr. A. J. Post, chief engineer; Mr. John McCord, superintendent of erection, and Mr. Michael Briody, assistant superintendent in charge. All rivet holes were drilled from the solid and all inspection was performed by R. W. Hunt & Co. Mr. E. D. Maxwell, field inspector.

A 40-Ton Wooden Guyed Derrick.

A guyed derrick with a 75-ft. mast and a 66-ft. boom of 40 tons capacity was recently designed and constructed for the erection of the 6,000 tons of structural steel in the Singer Building, New York. It assembled all the material in the 14-story Broadway extension and afterwards hoisted to the roof the 2,000 tons of material comprising the framework of the 63 x 63-ft. tower which rises 30 stories above the main roof to a total height of 612 ft. from the curb.

The mast and boom are single sticks of Oregon fir, the former having a diameter of 24 in. in the middle and tapering to 19 in. at the top and 21 in. at the bottom, where it is squared to receive the boom connection. The boom has a 21½-in. middle diameter and tapers to 17 in. at the point and 18 in. at the foot, where it is flatened on both sides to engage the seat on the mast. Both mast and boom are fitted with cast and wrought steel trimmings specially designed for simplicity, strength, easy and efficient operation and convenient manufacture, with all their dimensions computed to devolp a strength greater than that of the mast and boom. The principal castings are made from open hearth steel of from 60,000 to 70,000-lb. ultimate strength, and the links are tested to working loads of 80,000 lb. per square inch for the guys and 96,000 lb. for the boom and mast connections.

The top of the mast is accurately fitted in a cast-steel cap 12 in. deep, reinforced with a 4 x 1-in. wrought steel collar shrunk on. Two 8 x ¾-in. reinforcement plates about 8 ft. long are bolted on opposite sides of the mast with hooks at their upper ends engaging the ring of the cap. They are bored with a 2¼-in. pin of the 20-in. sheave mortised on the center of the mast which receives the hoist line and for a 1-in. bolt through the bottom of the 6½-in. gudgeon pin 4 ft. long, which projects 13 in. above the top of the cap. These bars pass underneath the split collar just below the cap, which is made with two 8 x 1¼-in. semicircular halves upset at the right angle flanges, which are bolted together with 3¼-in.

pins, receiving links made of 2¼-in. round iron. They pass underneath a collar just below the cap made with a single piece of 8 x 1¼-in. steel bent to a complete circle with the ends upset and bent 90 deg. to make flanges and bored to receive a horizontal 3¼-in. clamp bolt, which also serves as a pivot for a link made of 2¼-in. steel to receive the topping lift tackle. The flanges of this collar engage on their lower edge the shoulder of an upset vertical bar over the cap ring and secured at the upper end by a second ring fastened with screws. The gudgeon engages a cast-steel spider plate 3 in. thick and 40 in. in diameter with 8 equidistant 2¾-in. circumferential holes in each of which is welded a link made of 2-in. steel, which is 9 in. long and 4½ in. wide inside. Each link is intended to receive one, or if necessary two guys and the holes for the links and the gudgeon pin are all rounded so as to allow the spider plate to tip to an angle of nearly 30 deg. with the horizontal.

The foot of the mast is seated in a square cast-steel socket 30 in. high, with two vertical webs projecting from one side that are bored for the 2½-in. horizontal boom pivot and have a finished cylindrical seat to receive the rounded end of the boom. The lower end of the casting has a slightly tapered cylindrical extension 4½ in. long and 6 in. in diameter with a vertical hole in the center to receive the lead-lines passing over 12-in. sheaves mortised into the face of the mast just above the casting. The lower end of the cylindrical extension is faced horizontally to bear on a beveled hardened steel washer seated in the foot block; 3 x 3-in. bent angles are bolted to the upper edges of opposite sides of the foot-block to form projecting loops 6½ in. square, through which a horizontal bar may be placed to swing the boom. The foot of the boom is protected by a 14 x ½-in. bent plate accurately fitted to the curved seat in the mast block and has vertical side plates ½-in. thick, bolted on opposite sides to give bearing for the pivot. The upper end of the boom has two 6 x ½-in. reinforcement bars bolted on opposite sides and bored for the axis of the 17-in. mortised sheave and for the bolt through the lower end of the 2½-in. gudgeon, which projects 5 in. beyond the timber and engages a bent U-plate made of a 6 x ¾-in. flat with wings about 5½ ft. long, which are through bolted on opposite sides of the boom and have upset shoulders engaging the opposite edges of the split collar made from 8 x 1¼-in. steel bent to semicircular halves with the ends turned up 90 deg. and upset to their flanges secured by the 1⅞-in. bolts, which serve as pivots or links, made of 2¼-in. steel to receive the hoisting and topping lift tackles.

Although 10 pairs of guy lines may be used for the mast, only 8 lines were specified; each of them consists of 150 ft. of 1¼-in. 6-strand hemp center, crucible steel rope, with an ultimate strength of 58 tons. A 3-in. eye is rove to one end of each rope and a 6-in. sheave is provided at the other end for attachment to the deadman. The shackles and turnbuckles are designed to have a working stress of 38,500 lb. each.

In order to use the boom as a gin pole for hoisting the mast when the derrick is moved from story to story, it is provided with a cast-steel spider similar to that shown for the mast with a thickness of 1 in., and a diameter of 24 in. The spider has 6 links for attachment to ¾-in. wire ropes 55 ft. long with a 3-in. eye rove in each end and a shackle and turnbuckle for each line. The tackles for the 40-ton lifts are made with four blocks, each having six 16-in. sheaves and connections with a safe working strength of 85,000 lb. Each tackle is rove with 500 ft. of ¾-in. steel rope. Lighter tackles of 25-ton capacity have four blocks, each with four 16-in. sheaves and shackles each possessing a working strength of 60,000 lb.

The derrick is calculated for a load of 25 tons at a radius of 63 ft. or 40 tons at a radius of 47 ft. The combined dead and live loads at long radius give maximum stresses of 60,000 lb. in the topping lift and 47,500 lb. in the boom, and at short radius 61,000 lb. in the topping lift, 73,500 lb. in the boom, with the guys anchored at various distances from the mast to corresponding strain for the 25 and 40-ton loads, and their maximum radii are for the 25-ton loads, 14 tons at 30 ft., 18½ tons at 40 ft., 23 3-10 tons at 50 ft., and 25 tons at 60 ft. For the 40-ton loads they are: 20.2 tons at 30 ft., 26 tons at 40 ft., 30.3 tons at 50 ft., 34.3 tons at 60 ft., 37.8 tons at 70 ft., and 40 tons at 80 ft. The maximum reaction at the foot of the mast is 235,500 lb. for the 40-ton load at a radius of 47 ft., with guys anchored 30 ft. distance.

The derrick was designed by Milliken Bros., and was built at their Staten Island shops. The total weight with guys, but exclusive of the tackles, was about 10 tons, and it was moved two tiers, or about 25 ft. vertically at a time, as the erection of the building progressed, by the usual method of first unshipping the boom and using the mast as a gin pole to hoist it by the topping lift tackle to the tier above, where it was in turn guyed, and served as a gin pole to lift the mast. This operation only put the derrick out of service about 3 hr., each time it was moved. The largest load hoisted by the derrick at the Singer Building was one of the lower sections of the columns, and it was over 50 ft. long and weighed 28 tons. At one time it hoisted 400 tons of structural steel from the street to the 15th story, a distance of about 200 ft., in 6 hr.

Progress on Section 11, New York State Barge Canal.

Section No. 11 of the New York State Barge Canal extends about 12½ miles from the Sulphur Spring Yard Lock at Pendleton to Tonawanda, N. Y., and the work on it included in contract No. 19, awarded to the Great Lakes Construction Co., Buffalo, N. Y., consists essentially of enlarging and improving a portion of the present Erie Canal originally built by canalizing Tonawanda Creek. The present channel is through earth and rock and has no definite or regular dimensions of cross-section. In some places the creek is 15 ft. deep, but the average clear depth of the present canal is about 7 ft. The present normal water surface is at elevation 571, and the new grade at elevation 553 will provide a depth of 18 ft. until the removal of the Tonawanda Dam lowers it 5 ft., giving it a navigable depth of 13 ft., except at low-water stage of the Niagara River, when it will be reduced to 12 ft. The new cross-section will have a regular trapezoidal outline, 75 ft. wide at the bottom, with 1 to 2 side slopes, making the average width of top of cut about 150 ft.

The Head-Tower.

Eighty-Foot Bucket.

Derrick Handling Spoil Excavated by Dipper Dredge, Barge Canal.

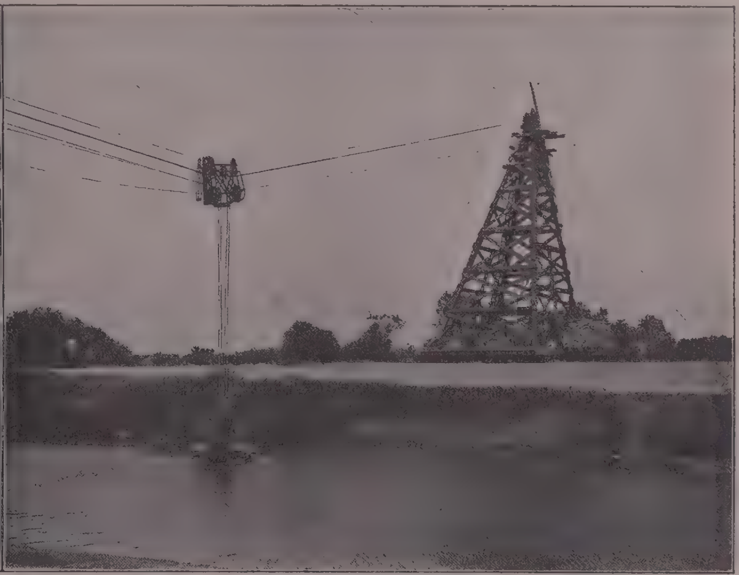
The bulk of the contract consists in the excavation of over 3,000,000 cu. yd. of material, much of which is submerged and some of which is obstructed by former constructions. It includes about 50,000 cu. yd. of pure gray limestone, which is blasted with 60 per cent. dynamite, and 3,032,000 yd. of earth, consisting of sand, silt, gravel and tough red and yellow clay. There are also about 7,800 yd. of concrete to be placed in bridge piers, abutments, approaches, and a dock at Tonawanda, and some work to be done in raising three of the five bridges at present spanning this section of the canal and in replacing the other two, which will require about 326,000 lb. of structural steel.

The wash wall on the side slope contains about 99,000 cu. yd. of dry rubble masonry, for which it was at first intended to provide a timber revetment, containing 10,000 piles, 15 ft. long; 2,000,000 ft. bm. of sheet piling and 315,000 ft. bm. of waling strips, but as the revetment has been found unnecessary on some of the other contracts, negotiations are at present in progress for its elimination.

The regimen of the creek is such that floods during the working season are not to be anticipated, and, as all the conditions and requirements were simple and well understood, the contract resolved itself principally into dredging and spoiling to the best advantage without interrupting traffic during the navigable season. In general, all of the excavated material is deposited on the right-of-way, at least 50 ft. clear of the berme or tow-path and at an average height of about 20 ft. above the surface of the water.

An important feature of the work is the elimination of hand labor and the excavation and handling of all material exclusively by steam machinery. The plant already installed includes two dredges and a Lidgerwood traveling cableway, the latter installed for the removal of 240,000 cu. yd. of earth and rock excavation in a length of 3,200 ft., of 620-ft. span and 10 tons capacity, with head and tail towers, respectively, 74 ft. and 64 ft. in height. The towers are of ordinary construction, heavily ballasted, and travel on 5-rail tracks of about 40-ft. gauge. The main cable is of the locked steel type 2¼ in. in diameter, with an ultimate strength of about 220 tons, and the operating ropes are of the Hercules type, ⅞ in. in diameter. The cableway is operated by an engine, said to be the largest ever installed for cableway service, located in the head tower. It has double 14 x 18-in. cylinders, reversible link motion, and three tandem friction drums, 51 in. in diameter, with 60-in. faces and special cork-inserted frictions, 72 in. in diameter. Each drum is provided with a powerful hand-brake and very heavy cast-steel gear, and the hoisting drums have a capacity of 20,000 lb. on a single line. The inhaul and outhaul branches of the conveying rope are made fast to opposite ends of the drum, and the latter is wide enough to wind all of the rope for the entire span in a single layer, thus preventing slipping and avoiding the wear which results from the use of a spool or winch type of conveying drum. The engine is equipped with two 75-hp. Economic boilers built for 125-lb. working pressure, a 200-hp. feed water heater, pumps and supply tanks, all located in the head tower.

Engine for Operating Bucket.


Method of Dredging Clay.

For handling rock the cableway is equipped with 8 x 8 x 2-ft. 10-ton automatic dumping steel skips, delivered to it from scows on which they are filled by the floating dredges. For earth excavation the cableway is designed to handle a 2½-yd. Hayward orange-peel bucket on a single-line hoist or an 80-cu. ft. clam-shell bucket hoisted on a 2-part tackle. It has a spread of 14 x 4½ ft, open, and the closing mechanism is operated by a six-part line. This bucket is of the standard type, manufactured by the Brown Hoisting Machinery Co., for use as an ore grab bucket, and, although subjected to very severe service, the repairs have been small and its operation satisfactory, so that the manufacturers state that they would make a new bucket for the same service on the same design, excepting some change of detail intended to better fit it for working under water, where the sand and grit cause considerable annoyance with ordinary buckets. The bucket has shown excellent efficiency in handling the material from old walls, piling, floors, etc., blasted out of the old canal. In some cases it has handled 4-ft. cubes of concrete and 12 x 12-in. timbers, 50 ft. long. In digging out the old tow-path it encountered cinders, one-man stone, sheet piling, oak flooring and tough red clay. The large stones sometimes prevented the bucket from excavating full loads, but this difficulty disappeared when it entered the clay, and the trouble there was to prevent it from taking too much and overloading the cableway. In digging from an irregular pile the bucket often works on its side, but still fills completely in every instance.

During October last this bucket and cableway excavated about 16,000 cu. yd., an amount considerably below the full capacity of the machine, on account of the delays occasioned by moving, by passing boats and because the excavation was very shallow. An average of about 30 trips per hour is made, and, allowing 2 yd. of material for each trip, about 1,000 cu. yd. are readily handled daily in two 8-hr. shifts. In soft material, where the bucket is completely filled, 1,500 yd. can be handled in 16 hr., and these amounts can be still further increased when the cableway is operated at the rate of 50 trips per hour.

A large amount of material has been excavated by a dipper dredge, dumped and transferred to the spoil bank by a floating and by a land derrick. The floating derrick has wooden shear legs, braces and boom, mounted on an ordinary wooden scow fitted with anchor spuds and equipped with a 10 x 12-in. 3-drum Flory engine, with steel gears, and American Hoist & Derrick Co.'s swinging engine and a Fitzgibbons marine boiler, and operates a clam-shell bucket. The structural work of the land derrick was built by the Dobbie Foundry & Machinery Co., Niagara Falls, N. Y., and it has a steel boom, 100 ft. long, with a capacity of 10 tons at an elevation of 25 deg. It is equipped with a 3-drum 10 x 12-in. main engine and a 2-drum 6½ x 8-in. swinging engine, both manufactured by the Flory Manufacturing Co., and operated with steam from a No. 11 70-hp. Economic boiler, made by the Erie City Iron Works. When making a cut to straighten one of the bends in the present canal this machine excavated in a single 8-hr. shift 14,302 cu. yd. bank measure, lifted it an average of about 30 ft. and swung it through an arc of about 120 deg. to the dump. The cut had an average depth of 20 ft. and a width of 75 ft. at the bottom and 155 ft. at the top, and a 66-cu. ft. Brown Hoisting Machinery Co.'s bucket was used. For the present service of handling the spoil a 2-yd. Page scraper bucket is used. The floating derrick is equipped with a No. 1 1½-yd. Williams' Faivrette bucket, which is of simple construction, requiring very few repairs and giving excellent satisfaction.

The contractor has now under construction by the G. H. Williams Co. a special revolving derrick, with an 85-ft. boom and 21½-ft. turntable, to operate a 2-yd. Page scraper bucket, handling 10 tons on a single line. It will be equipped with a 12 x 16-in. engine, with 30-in. drums and cut steel gearing, and a 9 x 9-in. double vertical-throttle reverse-type swinging engine, made by the Chase Machinery Co., Cleveland. Steam will be provided by an 80-hp. Economic boiler; the turntable will have a set of 40 steel wheels between 80-lb. upper and lower rails, and Hercules steel cable, manufactured by A. Leschen & Sons, will be used throughout.

Concrete is to be made with Portland cement, which, together with sand and crushed stone, will be stored on flat scows moored alongside a derrick scow, which will deliver to mixers placed on it, and will also deliver the concrete to the molds.

Work on this contract was commenced last June and is to be completed Dec. 31, 1910. The maximum force now employed is 80 men, which, however, will be increased during the season, when it is intended to operate part of the machines two shifts and others three shifts daily.

The work is under the charge of Mr. Frederick Skene, State Engineer, and Mr. William R. Hill, Special Deputy State Engineer. Mr. John P. Kelly is division engineer, and Mr. T. W. Barrally is resident engineer. Mr. D. D'Arcy W. Roper is engineer for the contractors.

DULUTH AND SUPERIOR combined received water-borne freight amounting to 7,840,000 tons in 1907, and shipped 26,947,000 tons, the receipts and shipments being valued at $34,787,000. This enormous freight movement occurred in only eight months.

THE CONSTRUCTION OF THE CITY INVESTING BUILDING, NEW YORK.

Among the loftiest and costliest commercial buildings in the world, that raise their enormous masses of brick and stone hundreds of feet above the streets of lower New York, the tallest and most imposing is the immense fireproof structure now almost completed for the City Investing Co., at Broadway and Cortlandt St., occupying an area of over 32,000 sq. ft. It has a contents of over 10,000,000 cu. ft. and a rentable area of 500,000 sq. ft. and will have been built, equipped and ready for tenants next May, at a cost of about $10,000,000, including the land value, in less than two years after the commencement of work in razing the buildings which formerly occupied its site. It occupies an irregular site, 313 ft. long and 124 ft. wide in extreme dimensions with fronts of 37 ft. on Broadway and 209 ft. on Cortlandt St. and has 27 stories reaching to a height of 355 ft. above the Broadway curb for the wing and two pavilions, while the central part of the building, about 50 x 200 ft., has 33 stories and extends to an extreme height of 486 ft.; far taller than any other similar structures, except the towers of the Singer and Metropolitan buildings. A general description was published in The Engineering Record of Nov. 24, 1906.

Besides the task of financing such a structure and providing for its profitable maintenance and operation, the problems in the design and construction of its difficult foundations, its vast and elaborate superstructure, the handling of 110,000 tons of materials and carrying on important mechanical operations in the congested district where it is located, where many different kinds of work were conducted simultaneously in the most restricted space, without material obstruction to traffic, injury to citizens or accidents to the public or among the workmen, is obviously an undertaking of enormous difficulties and its completion, now nearly consummated successfully, demonstrates the conspicuous ability of the engineers, architects and contractors.

The foundations of the building are rectangular concrete piers carried through quicksand to the deep underlying rock by the pneumatic caisson process. The frame work of the steel cage type is about 420 ft. high above the tops of the piers. The outer walls built of red brick, are faced with Indiana limestone up to the sixth floor, above which they are faced with white semi-glazed brick on the exterior and with buff brick in the court walls and are trimmed with terra cotta. All floors are 10-in. hollow tile flat arch construction with cinder concrete filling.

All steel work is insulated by hollow tiles forming rectangles enclosing the largest dimensions of the members and set in contact with the rivet heads, the spaces between the terra cotta and the steel being afterwards filled solid with cement grout. All plumber's and steam fitter's lines run up through the building alongside of columns and are separated from the columns by 2-in. terra cotta blocks; they are then enclosed with 3-in. blocks on the outside which are connected with the blocks around the column, thus forming a continuous rectangular pier. This gives a protection with a minimum thickness of 2 in. on the bottoms of girder flanges and from 4 to 6 in. on their sides and around the faces of the columns.

The entire sub-basement floor is a monolithic mass of 1:3:5 concrete 6 ft. thick, in which the pedestals and bases for machinery are embedded. It is intended to absorb all impact and vibrations and to resist a moderate upward hydrostatic pressure and is reinforced with twisted steel bars and large wires. All of the upper floors are made with 10-in. flat hollow terra cotta arches, leveled up with cinder concrete and the flat roof is of similar construction, covered with tar and 6 x 12-in. hard tile 1 in. thick. The partitions are made with 4 and 6-in. hollow terra cotta blocks laid up in mortar like ordinary walls without steel framing. The wood work in the building is reduced to a minimum and all of it is treated by a fireproofing process. The window sashes, doors and frames are kalamined, and all of the stair construction and that around the elevator wells is of steel, concrete or marble. Owing to the comparatively isolated position of the building, little apprehension was felt from exterior fire and the outer windows are not provided with iron shutters or wire glass except those adjacent to north and south side of the Broadway wing. A considerable increase in the weight and expense of the outer walls is due to the fact that in accordance with the general regulations of the building code of New York city, the thickness of walls must vary in direct proportion to the heights of the building irrespective of the fact that the walls are supported at every story; in consequence of this fact they attain a thickness of 36 in. in the lower part of the building.

Special pains were taken in the original design to provide for the advantageous location and installation of the extensive mechanical plant and the installation of the principal machinery and the running of the main pipe lines was commenced soon after the erection of the steel frame work and was carried on simultaneously with the main construction operations, thus greatly expediting the completion of the building and demanding great care and forethought to prevent conflict and delay between different operations. The magnitude of the equipment is indicated by the size of the 2,000-h.p. boiler plant and the 21 passenger elevators.

Work was commenced in July, 1906 by the Hedden Construction Co. in removing the old buildings previously occupying the site, and after they were torn down to street level operations were commenced about Sept. 1 by the O'Rourke Engineering Construction Co., sub-contractors for the substructure and excavation.

The first construction work done was in the underpinning of the thick walls of the 6-story Benedict Building which is enclosed on two sides by the new building. These walls had rubble masonry footings seated on the sand about 18 ft. below the Broadway curb, which were in such poor condition that great care was necessary in replacing them. Small pits were sheeted down to sub-grade in the open lot a few feet in front of the wall and permanent concrete footings laid in them to support the outer ends of needle beams inserted through the old wall just above the cellar floor in places where the interior of the building was accessible to the contractor. Small tunnels were drifted under the old footings in the planes of the main needle beams and auxiliary cantilever needle beams were inserted in them to carry that portion of the old wall below the cellar floor.

Where the interior of the Benedict Building was inaccessible, the wall was temporarily supported on low level cantilever needle beams fulcrumed on and reacting against its inclined shores seated in the exterior pits and gained into the face of the wall at their upper ends. After the walls were supported, a narrow continuous trench was excavated and sheeted down to sub-grade adjacent to its outer face, and the new footing was built in it and connected to the old brickwork in the usual manner as described in The Engineering Record of March 2, 1907.

The cellar floor of the old buildings was practically a continuous platform of concrete and solid granite masonry about 6 ft. thick which was very hard and strong, requiring about two months for its removal, which was effected with a large force of men and nine steam drills. The general excavation below the cellar floor was made with pick and shovel and was carried down to a maximum depth of 30 ft., about 8 ft. below the ground water level. Most of the spoil was removed by wagons hauled with teams up wooden inclined planes, except for the latter part of the work where the earth and sand was shoveled into steel buckets, hoisted by derricks and dumped into wagons at the street level.

When the excavation was nearly completed platforms 24 ft. wide were built at street level to provide for the receipt and delivery of materials by trucks. One platform extended the full length of the building from Broadway to Trinity Place, another 150 ft. long was parallel to it and a third 75 ft. long was transverse to them and connected them with Cortlandt St. The platforms were supported on three rows of piles except in some cases where framed trestle bents were used to facilitate their removal in subsequent operations. The outer rows of piles in the main platform directly supported the rails for a 21-ft. gauge track for a timber tower traveler equipped with four 45-ft., 15-ton derrick booms and having an 18 x 10-ft. clearance underneath to provide for the free passage of trucks.

There are in all 59 concrete piers, 18 of which are comparatively long and narrow with extreme dimensions of about 8½ x 37½ ft. to carry the wall columns and their adjacent counterbalancing columns in pairs. The remainder of the piers are from 6 to 10 ft. square. All of them were sunk with wooden pneumatic caissons about 12½ ft. high having walls of solid 8-in. timber and a temporary wooden deck 7 ft. above the cutting edge. The caissons, with a maximum weight of about 14 tons each, were delivered complete by trucks from the contractor's yard on Long Island and were unloaded by the traveler derricks and by three other movable stiff-leg derricks which set them in the required positions in the bottom of the excavation.

Before the caissons were sunk the piers on their decks were built up to full height with concrete deposited in 8-ft. courses in movable forms slipped upward as fast as the succeeding courses were set. After the concreting was completed air pressure was admitted to the working chambers and the caissons were sunk through quicksand and hard pan to solid rock at a maximum depth of 80 ft. and at a speed of sometimes as much as 2 ft. per hour. Owing to their great height and narrow width they were considered top heavy and special guides were provided to maintain their verticality during the earlier stages of sinking.

Large quantities of broken stone, cement and sand were stored in heaps in the bottom of the excavation and were delivered by wheelbarrows to four Ransome concrete mixing machines moved from place to place adjacent to piers or caissons which were being concreted. The machines discharged into steel buckets delivered by derrick booms to the pier moulds or to the working chambers of the caissons. The concrete was made 1:2:4 and 1:3:5 with Northampton Portland cement and in cold weather was mixed with salt water and protected by canvas covers under which exhaust steam was discharged. As many as six caissons were under pressure at once and the excavation and sub-structure work, including the removal of 4,500 cu. yd. of old masonry, 11,000 yd. of earth and old foundations and the laying of 11,000 cu. yd. of new concrete was successfully accomplished within the limits of the contract time of 120 calender days by an average force of 275 men in the day shift and 100 men in the night shift besides a continuous force of 20 sand-hogs.

Numerous small wooden buildings, offices, shops, store rooms, locker rooms, etc., were located in convenient places under the wagon platform and between the caissons. Air compressors were installed under the sidewalk clear of the caissons and together with the hoisting engines, concrete mixers and nearly all of the other machinery were operated by General Electric motors with current purchased from the New York Edison Co., thus avoiding the installation of a steam plant, effecting a considerable economy and time and space, and establishing an unusual precedent in the use of electricity on work of this character.

As the columns have maximum loads of over 1,700 tons each, it was necessary to distribute the pressure by I-beam grillages covering practically the entire tops of the concrete piers. The beams were carefully set on the level surface of the concrete, the distributing girders were placed transversely upon them and shimmed up with steel plates 18 in. wide at both ends, by which they were adjusted to exact levels and supported until continuous bearing was afforded for them by the 1:2 Portland cement grout with which the interstices between the grillage beams were filled. Some of the foundation girders were 8½ ft. deep, 5 ft. wide and 37 ft. long, weighing 105 tons each and were really compound structures composed of three parallel plate girders weighing 35 tons each which were delivered separately at night by trucks and lowered to position by two derrick booms acting together.

Cortlandt Street Front and Rear View of the City Investing Building.

The street platform used for the sub-structure work was replaced by a wooden falsework made with four-post framed transverse bents of 10 x 10-in timber carrying double lines of 20-in. longitudinal I-beam stringers on a track about 120 ft. long, for a traveler which consisted of a horizontal platform mounted on wheels and equipped with two stiff-leg derricks having 60-ft. 12-ton booms and weighing about 60,000 lb. exclusive of its engine. This traveler erected the foundation girders and the remainder of the steel work up to the third floor in the Broadway wing of the building and under maximum load required anchorage for stability with the booms at long radius. This traveler erected the 19-ton 2-story column sections in the Broadway front and on them placed the 25-ton double-web transverse girders 7½ ft. deep which carry the 23-story offset upper sections of the columns. Afterwards tackles were suspended from these girders and were used to fleet in columns and girders from the street, delivering them within reach of the traveler inside the building.

At a comparatively early stage of the erection, the traveler was replaced by 5 guy derricks and one stiff-leg derrick located so as together to command the entire area of the lot as well as the street front where they unloaded the trucks and when necessary passed the steel from derrick to derrick to interior portions of the building. Two of the guy derricks had 71-ft., 25-ton booms and three had 67-ft., 20-ton booms, all of them being provided with 8 guy ropes each and being shifted from one tier to the second or third tier above with an interruption of only about 5 hr. to the service. On account of the very heavy traffic in Broadway, all of the girders and columns for the Broadway wing were delivered at night and were handled with great rapidity, notwithstanding the fact that some of the heavy girders had to be fleeted 100 ft. horizontally by tackles suspended from the second floor girders. The steel superstructure was described in The Engineering Record of Dec 1, 1906, and some of the details of its erection were illustrated June 15, 1907.

After erecting the Broadway wing up to the third story the traveler was discontinued and its place occupied by a stiff-leg derrick before mentioned which erected columns and beams unloaded in Cortlandt St. by the guyed derricks which passed the steel through the buildings to it. This derrick, like the others, moved upward with the successive sections of columns, and unlike them was hoisted by means of a house derrick which lifted the mast, boom and sills together after the stiff-legs had been removed. The mast was guyed in the new position and so maintained until the stiff-legs were brought up and reconnected to it. Up to the 21st story the column sections were three stories long and above that they were two stories long and in all cases the derricks handled all materials connected to one section of the columns in each position.

Each derrick was operated by a force of seven men who handled an average of about 300 tons of steel per week. About 800 tons of steel which are contained in a typical three-story section of the building, were erected in an average time of 15 days. All material was stored at Greenville and delivered to the building by lighters and trucks and with the exception of the heavy girders brought to the Broadway entrance, was all unloaded by the two main derricks on the Cortlandt St. front. The lighters were unloaded at pier 11, East River, and the trucking was very difficult and expensive on account of the congested condition of the street and the enormous amount of material being delivered in Cortlandt St. simultaneously for this building and for the great twin buildings of the Hudson Terminal almost adjacent to them. Deliveries were arranged so that all of the columns for each tier were first received and erected after which the girders and beams for the same tier followed.

All of the columns supporting the hoisting derrick and such others as needed it were plumbed by X-bracing in the upper panels, which consisted of intersecting ¾-in. steel wire ropes with sleeve nut adjustments, of which perhaps 30 sets were used.

All field connections were riveted excepting those in the mansard roof which were bolted, and the ¾-in. rivets were driven at the rate of about 180 daily by each of an average force of nine riveting gangs, kept within about three stories of the erectors. The rivets were heated in ordinary hand forges and were driven by

Cleveland pneumatic hammers operated with two duplex air compressors located in the basement and delivering through a single riser pipe. The erection force consisted of about 115 men in all and their access to the work was usually facilitated by wooden temporary stairs maintained up to within about two stories of the derricks, above which they had to climb on the usual ladders.

The structural steel work has a total weight of about 12,000 tons and includes 92 main lines of columns. Work was commenced setting the grillages on March 5, 1907, and the erection of the columns was commenced one week later and completed Dec. 1st.

The 6-ft. layer of 1:3:5 concrete in the subbasement floor was hand mixed with Northampton Portland cement and 1½-in. broken stone and laid as soon as possible after the erection of the first tier of columns. About 5,570 cu. yd. of concrete were required for the floor and for the retaining walls which were solid slabs cast between vertical I-beams. The concrete was carried up above the tops of the cast pedestals of the columns and completely enclosed the grillages and foundation girders with a minimum thickness of 4 to 6 in. outside the metal. All of the sub-basement floor and wall surfaces below street level were water-proofed with hydrolithic liquid coating by the Water-Proofing Co., New York.

The steel erection was the index to all of the other building operations which were planned to succeed it as rapidly and continuously as possible, the first of them being obviously the floor construction, executed by the general contractor, which was commenced June 1st and completed February 15th. The materials for it and for the walls and partition formed a large part in bulk of the supplies required for the construction of the building above the street level and were wholly delivered by trucks and unloaded inside the building. The different entrances were so arranged and the movements directed that the trucks arrived in one place and entered the building, were unloaded and moved continuously forward to exit at another place without turning around.

The platforms were in all places wide enough for three trucks abreast and after the street floor was laid it, of course, provided considerably more space, which was kept clear to provide passageway enabling 10 or 12 trucks to be in the building at any time, although 7 was the average number unloaded at once. Materials, especially masons' supplies, were received continuously throughout the 24 hours, but an especial effort was made to have as much as possible delivered at night when it was unloaded, distributed and stored by a special force of about 150 men. As many as 72 loads of brick and 78 loads of mortar were received in a single day and considerable quantities were piled on the first floor for reserve supply, but as far as possible they were unloaded near one or another of the four pairs of high speed hoists installed by the W. A. Smith Elevator Co., dependent upon which machine ran nearest the spot in the building for which the material was destined. Each of them had a capacity of 500 lb., and could make the round trip to the 26th floor, 350 ft. high, in 50 seconds. The two center hoists ran above the 26th floor to the 32nd floor level and an additional outside roof hoist extended from the 26th to the 34th floor. From the hoists all materials were distributed in wheelbarrows on runways made with two or three 2 x 9-in. planks laid across the beam flanges.

The floor arches were laid in the usual way in Northampton cement motar mixed dry and furnished by C. L. Miller & Co. in 100 lb. bags, which were emptied into mixing boxes and wet as required. The cinder filling on the tops of the arches was applied in three layers. The electric conduits were set on top of the first layer and the spaces between them were filled by the second layer, after which all was covered to a depth of 4 in. above the tops of the beam flanges with the third layer. Before the last coat had set it was covered with the 1-in. finished surface of special composition, which secured a very uniform pleasing color and a smooth hard surface. It was composed of a mixture of Berkshire white, Medusa and Vulcanite cements, marble dust and grit. There were in all about 550,000 sq. ft. of this surface.

As fast as the floor arches were built the main riser lines for the water, steam and drainage systems were erected and the electric conduits put in place. This work was followed by the furring and column covering, corridor partitions, plastering, plumbers and steam fitters, electricians, mosaic, marble work, finished floors, trim, glazing, painting and finishing. The exact sequence of some items being, of course, changed to suit varying conditions. The walls contain about 8,500,000 red brick, 664,000 semi-glazed face brick and 670,000 buff face brick.

The construction of the brick walls was commenced at the 6th floor about the middle of July and was completed about the middle of February by the general contractor with a force of about 1200 bricklayers and laborers. This force also included the men engaged in putting in the terra cotta floor arches, which were commenced the middle of July and finished with the brick work. The white face brick have a special semi-porcelain finish and were supplied by Sayre & Fisher and scrupulously graded for color at the site. They were laid in a special motar made of marble dust, lime putty and Keene's cement, the dust being used to secure a little luster and the Keene's for its binding qualities.

The face bricks were, of course, laid up simultaneously with the red brick backing and the work progressed at the rate of two stories per week. In every seventh course of the face alternate bricks were bonded to the backing by concealed headers. Both the inner and outer faces of the walls were laid carefully to line and the space of perhaps ¼ in. between the backing and the face brick was thoroughly grouted at every course. The utmost care was taken with the finish of the face wall and it is believed that the beautiful appearance of the brickwork is unexcelled by any other building.

The bricklayers worked on continuous platforms 5 ft. wide extending the full length of the walls around the entire face of the building and suspended from Cavanagh apparatus and cantilever beams set 10 ft. apart in every window. Each cantilever carried two small drums actuated by a common worm gear that was commanded by an endless rope within reach of the bricklayers on the scaffolds. Light steel cables 100 ft. long were wound on the drums and from them were suspended the cross pieces on which the scaffolds planks were laid. The bricklayers followed the steel erectors so closely that the cantilevers were moved every third story to correspond with the erection and the full length of the suspension ropes was therefore not required on this work.

As fast as the walls were built the window openings were temporarily closed with muslin and during the severe cold the interior of the building was at first heated with about 160 coke burning salamanders which, after the steam risers and boilers were in position, were replaced by the permanent steam radiators put in temporary positions to permit the trim and finishing work to be completed around their final locations. Wide temporary stairways were provided for the convenience of the workmen and access to the upper floors was facilitated by the use of the permanent passenger elevators as soon as the first ones were installed. As already stated the soil pipes were run as soon as possible after the floors were laid and to them were connected in different stories four school sinks, which were enclosed in temporary wooden partitions and served as workmen's closets. They were under the constant supervision of inspectors who maintained them in a sanitary condition and prevented any of the workmen from occupying them more than five minutes at a time.

Very heavy roof platforms 12 and 15 ft. wide were built to protect the sidewalks on all the street fronts of the building. They had a capacity of about 1,000 lb. per square foot and were made with 4-in. planks on 12 x 12-in. transverse beams 4 ft. centers suported on 12 x 12-in. vertical posts 10 ft. apart. These platforms served for the unloading and temporary storing of the 5,900 cu. ft. of cut Indiana limestone furnished by the contractor, Mr. Wm. Bradley & Sons, for the facing of the first six stories of the exterior wall. The stone was dressed and mainly stored in the Brooklyn yard and was hoisted from the street and handled for the masons by two steam derricks and 35 breast derricks. The stone was set with Lafarge cement mortar making ⅛-in. joints and each piece was securely anchored by a galvanized steel strap engaging a slot and a hole cut in the upper surface to fully clear the joint space. The stone work was commenced about the middle of July and was completed Nov. 1st, by an average force of about 200 men.

About 3,000 tons of architectural terra cotta, furnished by the New York Architectural Terra Cotta Co., were used for the face trimming, each piece being securely anchored to the backing or to the steel framework. Terra cotta work was commenced by the general contractor, July 25, and completed Feb. 15. Plastering was commenced Nov. 1st, with a force of about 240 men. Carpentering and trim were commenced together Jan. 1st, with a total force of about 180 men employed by the sub-contractor, V. J. Heddon & Sons Co. The ornamental iron work and stairwork was commenced by the Hecla Iron Works in September with a force of about 125 men and the roof copper work was commenced in December by Smith & Dorset, with a force of about 40 men. The total force employed by the general contractor comprised as many as 1,200 men working in two shifts and the employees of the sub-contractors swelled the total number of workmen in the building to about 3,000 men.

The thorough organization of the force, the classification of the work and the system of ordering, checking and inspecting adopted alone made it possible to handle such numerous and diverse operations simultaneously in such a restricted area and avoid conflict and confusion. Everything was under the direction of the superintendent, who personally supervised and inspected all work of importance and directed operations in advance. All lines, levels and important measurements were given and verified by the contractor's engineer, who was constantly on the work and there were two architect's representatives to compare the construction with the drawings and specifications.

All materials required for the building were classified and billed and orders for all materials were placed as long as possible in advance. Inspectors were assigned to constant duty for the most important items, including the terra cotta manufactured at the New York Architectural Terracotta Works, Greenpoint, L. I., brick at the Sayre & Fisher Works, structural steel at the Pencoyd Plant of the American Bridge Co.; Portland cement at Northampton Cement Co.'s works, Stockerton, Pa.; and dry mixed mortar at the Clifford L. Miller & Co.'s mills. These men tested and inspected the products and made daily reports of finished materials and shipment which were kept constantly posted at the main office always showing by inspection whether the products were up to schedule delivery.

Other inspectors were detailed from the main office to inspect or report on any other supplies necessary, thus eliminating all uncertainty and assuring shipments in time to meet the requirements and still avoid unnecessary storage at the site. Dealers' representatives called at the building daily and received orders for the regular quantities constantly needed of standard materials like red brick, sand, crushed stone, etc., and whenever special deliveries were required, orders for them were placed a week or ten days in advance. About 1,000 cubic yards of sand and 1,000 cubic yards of grit and large quantities of red brick were stored during the winter at the dock, to insure against delays in shipment. Notwithstanding all this care, the principle difficulty in the construction of the building was to secure sufficient material to keep the maximum number of men constantly employed, although as many as 72 loads of brick and 78 loads or 6,240 bags of dry mortar were sometimes received daily.

Views of the City Investing Building during Erection, from Broadway and from Church Street.

A meeting of all the sub-contractors' foremen and of all of the principal foremen of the Hedden Co., was called daily at 9:00 a. m. in the superintendent's office, where Mr. Holmes presided and adjusted in the best interests of the entire work any differences or conflicts which might have arisen between different classes of work. The foremen and sub-contractors reported all difficulties, orders for extra work were given and two weeks' notice to start extra work was also made. The regular operations of the day and for the immediate future were planned and, if necessary, revised.

Much confusion was avoided and the rapidity and excellence of the work was promoted by a very complete classification of mechanics and their helpers and the laborers, the latter becoming so skilled in their special duties that unusually good results were obtained and the work advanced very smoothly. The principal organization was as follows: Head foremen of masons, seven masons sub-foreman; masons, mason tenders, mortar mixers; head foremen of carpenters, four sub-foremen of carpenters; carpenters. Machinery foremen in charge of elevator service, machinists. Head concrete foremen, two concrete sub-foremen. Cinder concrete foremen, concrete laborers. Head truck foremen, four truck sub-foremen, truck laborers who are employed only at unloading trucks and distributing material. Scaffold foremen, scaffold laborers.

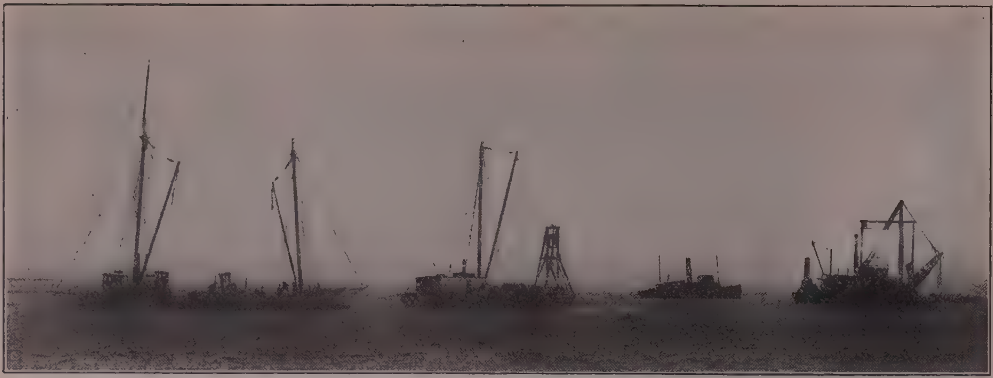
Each set of laborers was always kept constantly employed on one class of work only, so that they became especially skilled and efficient in it. This fact and the system of numbering all men employed in a certain class of work consecutively, as for instance all men in the mason department, from 1 to 300; all in the carpenters, from 300 to 500; all in the trucking from 500 to 800, and so on, made it comparatively easy to keep track of all men employed. Sub-foremen made daily reports of the details of labor upon which their men were employed. These reports, reduced to total hours, together with the quantities of materials used, were weekly posted, thus giving accurate cost records of all classes of work.

Each man entering the employ of the company received two brass checks of different shape inscribed with the same reference number. The circular one was his time check, taken out from the office whenever he commenced work and handed in by him when he passed out at noon or night. The other check, shaped somewhat like a four-leaf clover, was presented by him at the pay window Saturday afternoon and served as his identification and as a receipt for the contents of his pay envelope. This check was retained at the office and from it the record was made of his having been paid. The check was returned to him on Monday morning, after which there was no farther danger of a repeated claim for his pay being made.

Besides the record of commencing and leaving work twice a day or more, checks were made at irregular intervals, four times a day by the timekeeper's assistants, who went through the building recording every workman by number so that if he did not present himself for this identification no time was allowed for him subsequent to the last time when he did apear. The difficulty of keeping exact account of all over-time claims was very satisfactorily met by a special form of time-book ruled for one line each day in the month and five columns for each line. In two of these columns were recorded the number of hours for the regular morning and afternoon shift, the other three provided for recording any possible overtime, which must necessarily be put in before eight in the morning, between 12 and 1 or after 5 o'clock at night. The pay-roll as made up from these time sheets was compared with the distribution sheets showing the time on different classes of work as made up from the sub-foremen's report. These two checked very closely, although there were necessarily slight discrepancies. Some idea of the magnitude of the work and the care with which it was executed is given by the amount of the pay-roll, which was as much as $26,000 a week and by the clerical organization in the superintendent's office which included a chief clerk and about 14 assistants, timekeepers, receiving and stock clerks, stenographer and typewriter.

Mr. Frances H. Kimball is the architect of the building, Weiskopf & Stern are the consulting engineers, Griggs & Holbrook electric and mechanical engineers, Mr. Wm. C. Tucker sanitary engineer, and the Hedden Construction Co., Mr. E. A. Holmes superintendent, general contractor. Among the principle sub-contractors there are besides those already mentioned, the O'Rourke Engineering Construction Co., for sub-structure; the American Bridge Co., for fabrication of structural steel work, and Post & McCord for its erection; Messrs. Wm. Bradley & Sons, cut stone; Hecla Iron Works, ornamental iron; National Fireproofing Co., terracotta brick and tile; N. & W. J. Peck, red brick; Sayre & Fisher, enamel brick; Wells & Newton, plumbing; L. H. Prentice, steam-fitting; J. H. Shipway & Bro., marble work, and McNulty Bros., plasterers.

The Uintah Ry., 54 miles long, was built between Dragon, Utah, and the Denver & Rio Grande Ry. for the sole purpose of transporting gilsonite from its mines.



Flotilla Used on Quincy and Hull Outfall Sewer.

SOME CONSTRUCTION METHODS ON METROPOLITAN WORKS.

By Howard S. Knowlton.

In the construction of the extensive sewerage system in the Boston Metropolitan District a number of special problems have from time to time originated on the work, and in the following paragraphs some of the methods adopted in the handling of the field work are described.

The Metropolitan district is divided into two parts, dictated by physical and geographical considerations, with an independent harbor outfall for the larger portion north of the Charles River, designated as the North Metropolitan System, and an area known as the Charles River Valley District, on the south side of that stream. The Boston main drainage sewers are provided with a separate outlet into the harbor. The Metropolitan work is mainly of a trunk line character, and the examples of construction methods cited below are all taken from outside the Boston main drainage sewer district.

In the construction of the Quincy and Hull outfall two lines of 60-in. pipe were laid on the harbor bed in strong tidal currents. These extend from Nut Island to a point about one mile below low-water mark in Boston Harbor. The two lines have an aggregate length of 10,844 ft. The pipes were laid in trenches dredged in the bed of the harbor and are spigot and socket pipes, 1½ in. thick and weigh six tons per standard 12-ft. length. The bottoms of the pipes have an average depth of 12 ft. below the bed of the harbor, and the trench is dredged 2 ft. deeper, to a maximum of 53 ft. below mean high water. The trench was made 10 ft. wide at the bottom, with sloping sides, to give a mean top width of about 30 ft. The dredging was in stiff clay. The flotilla used in the work are shown in the accompanying photograph. The dredge was towed at the head of the line and was followed by a pile driver and by two diver floats, one being used in lowering the pipe and the other in tending it.

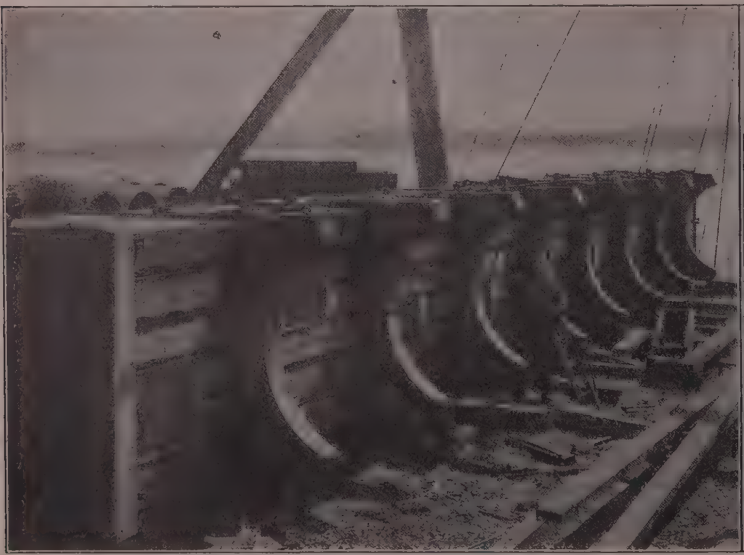
In the trench 10-ft. piles were driven in 5-ft. bents of two piles each at intervals of 6 ft. These were capped by spruce timbers set to the required grade. The piles were driven with the assistance of a vertical telescopic guide box, 35 ft. long when enclosed, resting upon the bed of the harbor and capable of adjustment to varying depths of trench and conditions of tide. This box is illustrated herewith. Inside the box was placed a leader fitted with rollers to prevent it from sticking in the box, and the piles were driven inside the leader. A cylindrical hammer 10 ft. long was used to drive the piles, and the outfit was carried on a 75-ft. lighter.

The pipes were laid in 48-ft. sections, consisting of three lengths of ordinary spigot and socket pipes and one length having the spigot turned to a slight taper for a length of 5.5 in. This spigot was temporarily inserted upon the wharf into the bell of the pipe which was to form the leading end of the section, and the lead space entirely filled with lead, but without calking. The spigot was then withdrawn, to be used as the rear end of the following section. The four pipes forming a section were then arranged in their proper order upon a floating caisson, shown in an accompanying illustration. The caisson was lashed to the side of a second lighter, the three ordinary joints being run and calked in the ordinary way. The caisson was a heavy timber structure, of a special design patented by the contractor and was 6 ft. square outside and 52 ft. long, built of 6-in. hard pine and divided by eight transverse bulkheads into nine compartments which could be separately flooded. On one face of the caisson eight timber saddles, shaped to the external contour of the pipes, served as a resting place for the pipe section, which was firmly secured by chains and turnbuckles. When filled with water the caisson was sufficiently heavy to sink, but when empty its buoyancy was sufficient to support a section weighing about 24 tons. On being released from the lighter the caisson immediately turned over, so that the pipes were suspended from it in the water. Then through openings controlled by plugs the compartments were sufficiently flooded to sink the whole.

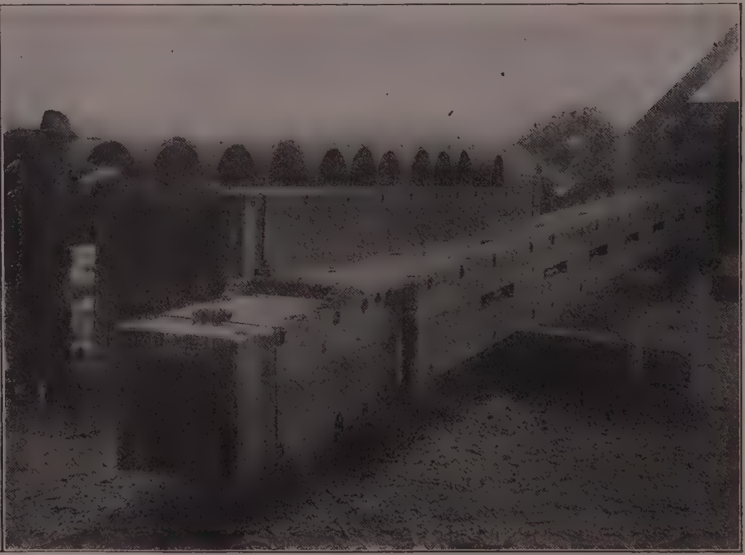
Arrived at the bottom and still attached to the caisson the pipes were adjusted by divers to line and grade upon the caps, and the tapered spigot was drawn home into the leaded bell of the preceding section by means of ratchet jacks actuated by levers. For the latter purpose the leaded bell was temporarily fitted with a collar provided with four guides to insure the entry of the tapered spigot without damage to the lead mold. When the pipes were finally secured in position by wedges spiked to the pile caps the caisson was filled with water, thus rendering it too heavy to float, and released from the completed section. It was then hauled to the surface by steam winches on the lighters, and the water was forced out of the compartments by an air pump. The special joint between the sections was calked before the excavated material was backfilled from the scows into the trench and over the pipes.

This work was begun at the outlet, which consists of a special quadrant bend about 11 ft. in length and weighing about 11 tons. The outfall pipe is surrounded by a timber casing 13 ft. square and 10 ft. deep, projecting 2 ft. beyond the extreme dimensions of the pipe and filled with Portland cement concrete. The outlet was lowered into position from the lighter by means of a derrick and steam winch.

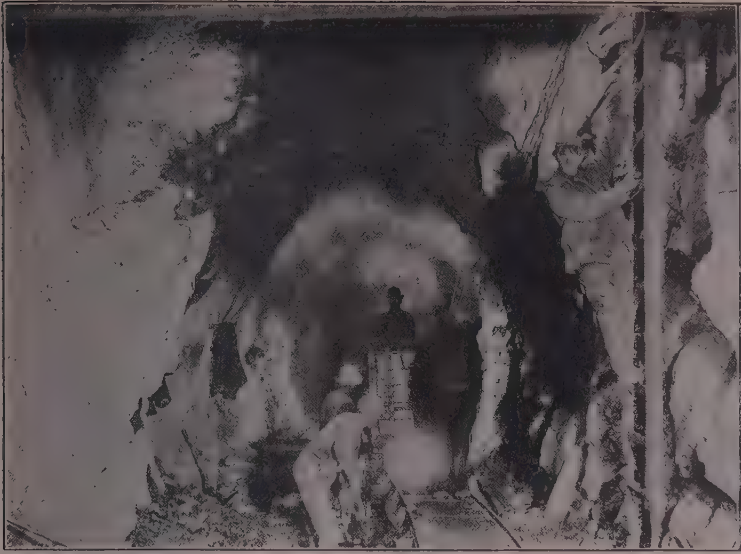
The largest concrete-lined tunnel thus far driven by the board is located in the town of Hyde Park. This tunnel is 5,300 ft. long, has a section of 9 ft. 3 in. x 10 ft. 2 in. and pierces the divide between the Stony Brook and Neponset River basins. The excavation was in rock, generally in hard felsite. A photograph is shown of the excavation in the tunnel heading. A Portland cement concrete arch was adopted in the tunnel in place of the usual brick arch, except for a length of 79 ft. under the New York, New Haven & Hartford R. R. The concrete arch and side wall backing were first put in place, followed by a concrete invert 10 in. in thickness. The invert and sides were then lined with 4 in. of Portland brickwork. These operations involved an average of 2.5 yd. of concrete per linear foot, and 0.203 cu. yd. of brickwork, with an average rate of progress on the concrete of 120 lin. ft. per week, and 293 lin. ft. on the brickwork.

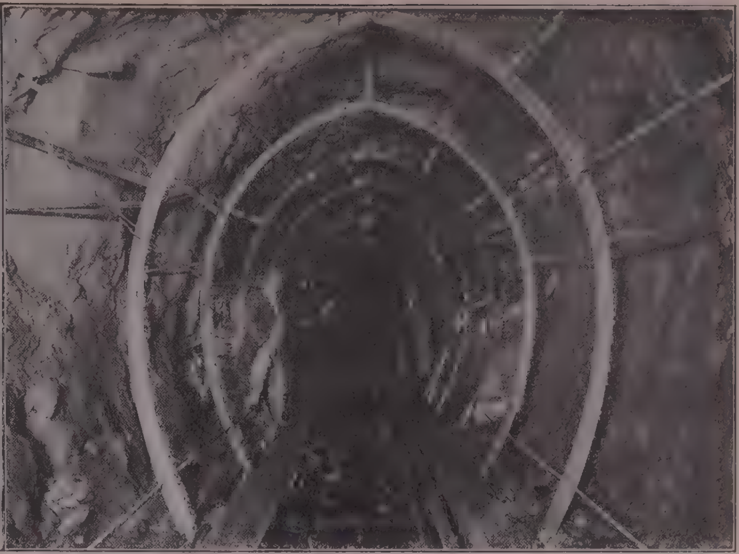


Floating Caisson, Quincy and Hull Outfall.



Telescopic Guide for Driving Piles.


Tunnel Excavation at Hyde Park.


Steel Ribs in Place, High Level Sewer.

The contractor's plant included a single-cage elevator for lowering materials into a central shaft 65 ft. deep. A gravity mixer was used for the concrete, delivering into cars, with a capacity of about 2.5 cu. yd., and hauled through the tunnel by a small locomotive. Flanged sheet iron plates, 5.5 ft. long and 16 in. wide, supported by 3-in. I-beam ribs, carried down to the footings of the side walls, were used for the concrete arch. A coat of thin oil applied to the lagging insured a smooth surface finish on the removal of the centers. The tunnel was kept dry by a 6-in. underdrain leading to the shaft, where the water was lifted by a 4-in. pump and discharged at the surface. The volume of water handled was about 150,000 gal. per day.

In the construction of a 9-ft. circular sewer in West Roxbury a part was done by day work, the pneumatic process being used. A pressure of 15 to 17 lb. was employed, and this was found sufficient to keep the water out of the headings, although the ground water stood at an elevation of about 32 ft. above the sewer invert. The excavation was in sand, with some gravel, the sand being very fine in some places. The roof of the headings was supported by flanged steel plates, 3.5 ft. long x 1 ft. wide, held by metallic sewer braces acting against a longitudinal needle-beam in the axis of the heading. The plate lining was carried down so as to occupy about two-thirds of the entire periphery of the headings. The cross-section of the sewer structure consists of a lining of brickwork approximately 12 in. thick, built directly against the interior of the plates.

In connection with this work a second shaft was driven at Monument Square, 43 ft. deep. The upper 20 ft. consisted of five sections of steel cylinder, 6 ft. in diameter, resting upon a timber deck 20 in. thick. The remaining 23 ft. of shaft below the deck, together with about 75 ft. of tunnel in very fine sand, were driven in each heading by the use of compressed air and a horizontal air lock at the surface, connected with the vertical cylinder. Air locks were installed in the completed sewer after these 75 ft. lengths had been driven and lined, and then no further use was made of the surface air locks. An effort was made to drive the tunnel with sufficient accuracy to require a brick lining only 12 in. in thickness, but, owing to changing conditions of sand and water and other difficulties, the thickness of the brickwork varied considerably, averaging about 15 in. The average rate of progress on the pneumatic tunnel was 22 lin. ft. per week.

At the present time a tunnel is being built under Perkins and Chestnut Sts., West Roxbury, extending past Jamaica Pond in the direction of Brookline. The section is wholly in tunnel, at depths varying from 70 to 20 ft. below the surface. The length is 3,123 ft. Passing Jamaica Pond, the excavation is 35 ft. below the ordinary water surface of the pond. Owing to the peculiarly dangerous character of the work, it is being constructed by the board on the day-labor basis, with pneumatic pressure. The work has now advanced in two headings, east and west of a central shaft. The work is being done in a residential district of the better class, so it was considered advisable to handle it in as inconspicuous a way as possible. The shaft leading down the tunnel is circular, being 8 ft. in inside diameter, with 12-in. brick walls. This shaft was built from the top downward. Steel cylinders 20 ft. long were first sunk in the street and then lined with 12-in. brickwork; excavation then proceeded in depths of 3 ft., secured by polings. The masonry below the steel casing was suspended by rods from the casing itself.

This method of shaft excavation was pursued for a depth of 57 ft. below the surface, at which depth water was encountered. An air lock was then introduced at the head of the steel cylinders on the street, and an air pressure about 6 lb. maintained. The completed shaft is 70 ft. in depth. The east heading has now advanced a distance of about 1,800 ft. from the shaft, and the westerly heading has advanced about 2,000 ft. The vertical air lock was removed last December, and horizontal locks have been constructed in each heading. The plant for carrying out the work consists of 375 hp. in boilers, three Rand air compressors of 75 hp. each, a hoisting engine at the shaft and two 100-light dynamos.

In the easterly heading the air pressure was 6 to 8 lb. For 600 ft. the excavation was in sand, gravel, quicksand and clay, with occasional boulders and short lengths of ledge. At this distance from the shaft there appeared solid ledge in the botom of the headings, and for a length of 150 ft. the tunnel heading advanced into the sloping face of the ledge. To minimize the shocks from the blasts on buildings near the line of the

West Heading, West Roxbury Sewer.

East Heading, West Roxbury Sewer.

tunnel, the air pressure has been maintained in the heading while the rock excavation has been in progress. An average progress of 22 ft. per week has been made, while the maximum progress has been 41 ft.

The excavation for the westerly heading has been through fine sand, coarse gravel and quicksand in alternate layers, with occasional boulders. An air pressure of about 6 lb. was maintained in the heading near the shaft, and the methods were similar to those employed on the West Roxbury circular sewer described above. The plates used in this kind of work were 36 in. long and 12 in. wide, the jacks being 1.5 in. in diameter, and the needle-beam made up of four 4-in. steel angles bolted together and stiffened by timbers. The average diameter of the tunnels through the rock section is 10 ft.

In some extension work from Winchester St., Brookline, toward Allston, a pocket of peat was encountered for a distance of 315 ft. Here the sewer was supported on concrete piles 12 in. square, reinforced with four ¾-in. steel rods. The piles were made by the board in forms on a platform outside the trench, and when these hardened were carefully driven with an ordinary drop-hammer pile driver. Where the pile foundation was placed the sewer was further strengthened by Ransome twisted steel bars, ¾ in. square, laid longitudinally in the arch, side wall and invert of the sewer, about 18 in. center to center. Three twisted steel bars, ¾ in. square, were placed over each pile bent. The sewer for this section is 5 ft. 9 in. wide x 6 ft. high, of horseshoe section. Concrete was used as the construction material, and the walls were 12 in. thick.

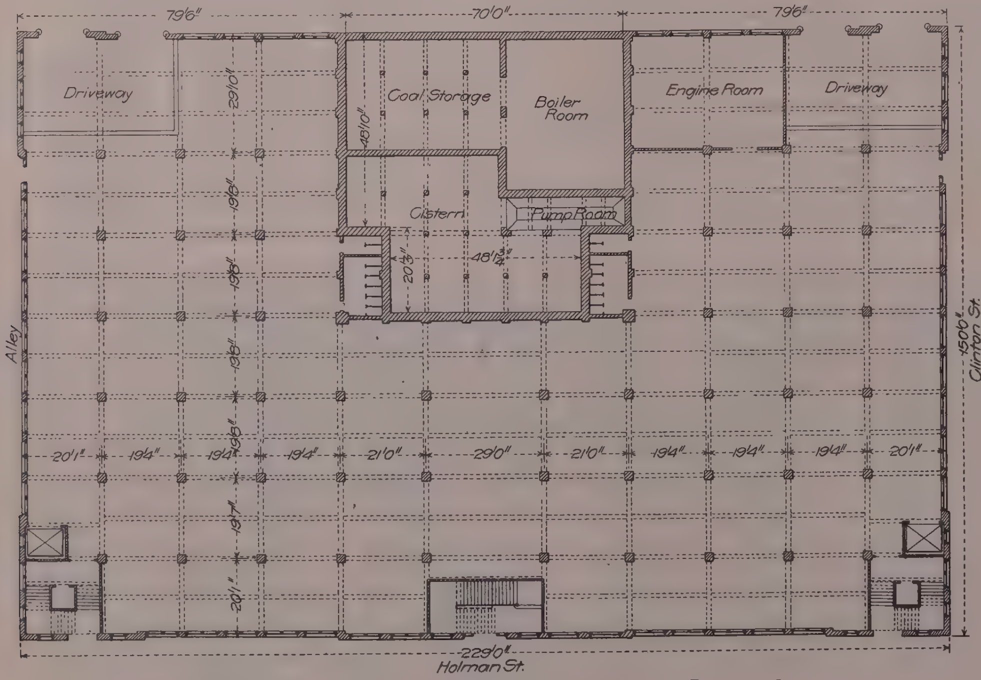
The Weight of Bridges.

The weight of bridges can be estimated approximately, according to Mr. E. K. Morse, by formulas he gives in a recent number of the "Proceedings" of the Engineers' Society of Western Pennsylvania. The first of these is for single-track, pin-connected, through-truss structures with open floor systems, and has the form $W = 7\frac{1}{2}L^2 + 500L$, where W is the total weight of the steelwork and L is the extreme length of the structure. For double-track structures of this class the formula is $W = 12L^2 + 1000L$. For ordinary single-track, open-floor deck plate-girder bridges the formula is $W = 10L^2 + 350L$. These structures are assumed to be designed for Cooper's E50 loading.

The Fort Wayne Lamp Works of the General Electric Company.

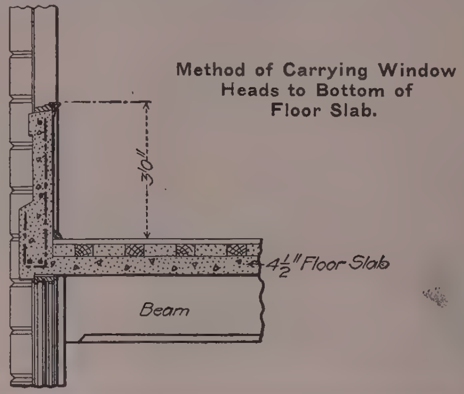
During the past summer, a new four-story reinforced concrete factory building to house the incandescent lamp works of the General Electric Co., was erected at Fort Wayne, Ind. The plan of the structure is U-shaped, with a frontage of 229 ft. on Holman St., and a depth of 150 ft. on Clinton St., the other two sides of the building being bounded by driveways, thus affording unobstructed light on all sides. The court at the rear of the building is approximately 70 ft. square, out of which area two rectangles in the inner angles of the court, measuring about 11 x 20 ft. each, are taken for the toilet accommodations on all four floors. In this court, depressed beneath the level of the surrounding property, have been placed a coal pocket and a cistern, while a boiler house and a pump room rise one story, being placed next to the engine room, which is within the building proper.

Construction in Progress on the Fort Wayne Lamp Works.



Plan of Fort Wayne Lamp Works of the General Electric Co.

The structure is provided with three main entrances on Holman St., the one in the center leading to the offices on the second floor of the building, and those in the ends to all of the floors, the latter being intended for the use of the employees. The stairways are completely enclosed by reinforced concrete walls cutting them off from the remainder of the building, and insuring their safety in case of fire. The stairways themselves are of reinforced concrete, fitted with Mason safety treads. All of the doors leading from these stairway enclosures and also those in front of the elevators are of an improved fireproof type.



Method of Carrying Window Heads to Bottom of Floor Slab.

In the far corners of each wing driveways and loading platforms for the receipt and delivery of materials are provided within the building itself.

The structural material throughout is reinforced concrete built on the skeleton type, the walls between the pilasters being filled with windows, thus giving exceptionally good lighting. The columns are spaced on about 20-ft. centers each way with the exception of wider bays in the center of the main part of the building, at right angles to the Holman St. front, and in the end bays of both wings. The pilasters in the walls are on about 10-ft. centers, corresponding to the spacing of the beams, so that the latter in all cases carry their loads, at the wall line, directly to pilasters instead of transferring them to girders in the wall.

The maximum size column used is 26 in. square, but the majority of those in the first story are 23 in. The columns on the remaining floors are likewise of square section, decreasing in size as the load diminishes, the minimum, carrying the roof, being 10 in. square in the fourth floor. The column reinforcement consists of twisted steel rods, one in each corner, tied together by ¼-in. binders spaced 12 in. apart. The style of reinforcement is similar for the pilasters, using the same kind of binders with the same distance on centers. It may be noted here that the reinforcing steel throughout the structure is of twisted steel bars, there being, however, a few exceptions, for shrink bars and those that take negative moment, which will be referred to later.

The maximum girders, having a span between centers of bearings of about 30 ft., are 15 in.

Rear View of the Fort Wayne Lamp Works.

View of Suspended Piping and Window Area.

wide, 2 ft. 9 in. deep and are reinforced with five 1¼-in. bars in the lower plane and, in an upper plane, with four 1-in. bars which turn up at the third points to take the shear. The latter bars extend beyond the centers of the columns into the adjoining spans a distance of about 2 ft. 6 in., there being some variation in this dimension to meet particular conditions. Stirrups of 1 x ⅛ in. strips are spaced on approximately 12-in. centers both in beams and girders, beginning at about the quarter points and extending to the bearings. These are punched with holes at the top through which ¼-in. bars are passed, extending out on either side into the floor slab to care for the negative bending moment.

The longest beams have a span of 29 ft. between centers of bearings, are 12 in. wide, 2 ft. 3 in. deep and are reinforced with four 1¼-in. rods in the lower plane, and three 1-in. rods which are turned up to take the shear.

The live load provided for in the design of the floors is uniformly 150 lb. per square foot. The slab is 4½ in. thick reinforced with ½-in. twisted bars on 6-in. centers between adjacent beams. Shrink bars of ¼-in. plain round steel are placed at right angles to this reinforcement on 24-in. centers. Wooden sleepers 3 x 4 in. are laid on the floor slabs, and the space between filled with cinder concrete, over which is a 1⅛-in. maple floor. As the casting of the beams, girders and floor slabs progressed, hangers were inserted wherever necessary for carrying steam pipes, compressed air lines, and the pipes of the sprinkler system.

One of the noticeable features in the design of the building is the method of carrying the windows up to the bottom of the floor slab of the story above. The arrangement is shown in the accompanying sketch. It allows of an increased depth in the windows, adding greatly to the lighting area, and places that area high, securing thereby the better diffusion of light over the floor. The stories are uniformly 15 ft. high and only the bottom 3 ft. of the walls between pilasters are filled with concrete, the remaining 12 ft. being devoted to lighting purposes. Ribbed glass is used in the upper part of the windows so as to diffuse the direct rays of the sun. On one side of the building, the west end, where there was danger of communication of fire from adjoining buildings, the window frames and sash are of heavy galvanized iron, glazed with wire glass.

As is shown in the accompanying plan, the court between the two wings at the rear of the building is divided into three parts, the coal storage pocket and the cistern being depressed below ground level, while the boiler room, in addition to extending a story beneath the surface, rises one story above it. The pump room, built as a separate compartment at the end of the boiler room, is directly over the cistern, the floor of the latter directly beneath the pump room being depressed to form a sump. When the excavation of the building walls around this court was started, at the same time as the foundations of the remainder of the building, it was thought that the underlying strata consisted for a considerable depth of a tough, blue clay, which is used as a foundation for practically all the buildings in Fort Wayne. This blue clay did extend over the entire area of the building to the depth to which it was desired to carry most of the foundations, but because of the depressed area within the court, the foundations of the walls around it had to be carried considerably below the level of the others. When the excavation for this purpose was made a stratum of quicksand from 3 to 4 ft. deep was discovered, the sand being very fine and saturated with water. Four-inch tongue and groove sheet piling was immediately resorted to for retaining the sides of the excavation, and when the latter had passed through the quicksand layer, a stratum of very hard clay, mixed to some extent with gravel, was encountered. The discovery of this quicksand naturally caused some anxiety regarding the stability of the rest of the building and borings were accordingly made over the entire site to discover the exact nature of the underlying ground. These showed that there was a 4-ft. layer of stiff blue clay between the bottoms of all of the footings and the top of the quicksand layer over every part of the area, and that the quicksand layer varied in thickness from 2 to 5 ft. Beneath it the solid clay mixed with gravel was encountered in all the borings.

The decision was therefore reached to clean out the quicksand layer over the entire area of the court and to build the structures within it on the solid stratum beneath, while the footings of the remainder of the structure were allowed to remain as first designed, with their bottoms about 4 ft. above the top of the mushy stratum. A line of sheeting was accordingly thrown across the open end of the court, cutting off whatever quicksand there was in the surrounding property from the court area. The sand was so fine and contained so much water that it was dipped out in buckets and hauled away in water-tight garbage carts. In many places it was necessary to caulk the sheeting in order to effectually prevent the filling of the excavation.

Even after the bottom stratum had been uncovered over the entire area, it was thought that there might be a considerable water pressure upon the walls and floors of the cistern, coal storage

Views of Beam Reinforcement in Place and Concrete Pouring in Progress.

and boiler rooms, and a heavy reinforced concrete slab was, therefore, put in over the whole area and, in addition, the sides and floor were thoroughly water-proofed. This floor slab consisted of an 8-in. layer of concrete reinforced in both directions by ½-in. twisted bars on 8-in. centers. On this was laid a waterproofing sheet consisting of five layers of felt and asphalt. The waterproofing was then covered with a 4-in. layer of concrete. A similar waterproofing layer was placed against the outside of the building walls surrounding the excavation and an 8-in. wall cast in front of it.

Ground was broken for the building on March 25 and the foundations, except in the court, were all completed on April 6, 1907. The difficulties with the quicksand above mentioned caused some delay in placing the foundations and the work on the first story was not started until April 29. The structure was finally completed, as far as the structural features are concerned, on July 17, which, allowing for Sundays, holidays and rainy days, when no work could be done, made a total of 79 working days.

Virginia spruce was used throughout for the forms which, with good handling, lasted throughout the construction. A clean-out slide was placed at the bottom of all columns forms so that all rubbish, dust and sand could be removed before the column was cast.

The forms on the outside wall were removed after three to four days, the surface carefully rubbed over and then covered with a thin coat of white marble dust and Lafarge cement. While this application was in progress the walls were kept constantly sprayed to prevent their drying and dusting.

The power equipment consists of two 260-h.-p. Sterling boilers, two underwriters' fire pumps of 1,000-gal. capacity for the sprinkler system, supplied from the cistern in the court, and three 100-kw. Curtis turbines driving 220-volt, 60-cycle, 3-phase alternators. The coal supply room has a storage capacity of about 500 tons and the cistern will hold about 120,000 gal.

The concrete, which for the entire structure was a 1:2:4 mixture, was mixed in a Foote steam-driven mixer, and raised to the floor level where desired by a hoisting elevator driven by a Lidgerwood hoisting engine.

The building was constructed and designed by the American Concrete-Steel Co., engineers and contractors, Newark, N. J., of which Mr. John T. Simpson is president. Mr. Joseph Shore was the superintendent for the contractors. The supervising architects were Wilson, Harris & Richards, of Philadelphia, Pa.

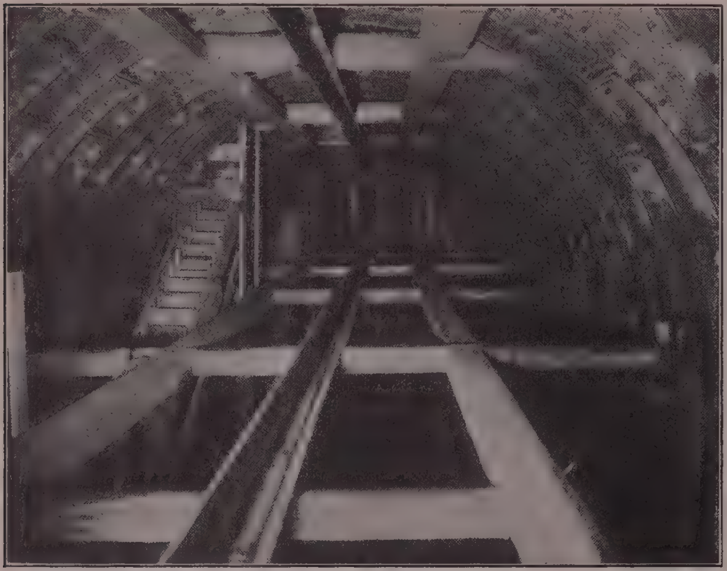
PENSTOCK WITH REINFORCED CONCRETE LINING AT THE NORTHERN ALUMINUM WORKS, SHAWINIGAN FALLS.

One of the first purchasers of hydraulic power developed by the Shawinigan Power Co., was the Canadian branch of the Pittsburg Reduction Co., called the Northern Aluminum Company. About seven years ago it installed a plant of about 20,000 h.p., which received water at a nominal head of 150 ft., through a penstock from the Shawinigan Power Company's power house, which derives a supply of about 50,000 h.p. from a high level canal, delivering through several steel penstocks laid in open cut to the turbines at the low level whence they discharge into the lower bay of the St. Maurice River near the mouth of the Shawinigan River, as described in The Engineering Record of April 28, 1900.

Recent extensions of the Northern Aluminum Company practically duplicated their original plant, and it was at first intended to locate the new power house adjacent to that of the Belgo-Canadian pulp mill at the low level on the banks of the Shawinigan River about one-fourth of a mile upstream from the original power house. The pulp mill power house is supplied through a steel penstock, also laid in open cut and in tunnel from a forebay in the St. Maurice River where the concrete bulkhead wall 40 ft. high was originally pierced for a second 12-ft. steel penstock which had never been installed. In order to connect this penstock with the proposed site of the new power-house, it was necessary to tunnel through a hill rising about 50 ft. above the intake level. The excavation for this tunnel was commenced from a portal in the hill between the upper and lower levels near the pulp mill power house but was discontinued after about 50 ft. had been excavated and it was found that the proposed site for the power house was not a satisfactory one.

A new site was then chosen for the new power house on the banks of the lower bay of the St. Maurice River, adjacent to the old power house where satisfactory rock foundation was obtained and provision was made for supplying it through a single steel penstock 13 ft. in diameter and about 300 ft. long, the upper part of which connected to a tunnel 1,000 ft. long, lined with reinforced concrete and extending from the top of the hill to the short steel connection already provided in the bulkhead wall of the forebay.

The tunnel was driven with four headings, one from each end and two from a shaft about 300 ft. from the upper end. In order to make connection with the steel thimble already built in the bulkhead wall, a 40x25-ft. open cut about 40 ft. deep was sheeted down with two upper tiers of 3-in. square edge planking and a lower tier of 4-in. splined planking, all driven by hand as the excavation advanced. The material excavated was blue clay readily cut with spades and handled by 1-yd. tilting steel buckets, handled by an A-frame derrick with a 50-ft. boom operated by a double-drum hoisting engine, manufactured at Welland, Ontario, Canada. Only a small amount of water was encountered, which occasioned no difficulty and was readily cared for by a 2-in. steam siphon.


Looking Down the Shaft.

Completed Timbering.

Simultaneously with the open cut excavation the regular excavation was commenced at the lower end portal, and the intermediate shaft was sunk. The shaft excavation was lined with cast-iron rings 14½ ft. in diameter and 2 ft. long, which had been provided for the abandoned tunnel already referred to. The segments about 3 ft. long were made in sets of 14, with key for each ring, and weighed about 150 lb. each. They were rough castings with cored bolt holes and no finished surface. The first ring was assembled on the surface of the ground and excavation commenced, undermining it and allowing it to gradually settle its full depth when a second course was added on top, and so on, until three courses were in position below the ground level, and one above. It was then found that the exterior friction would soon prevent the descent of the ring and no further attempt was made to assemble the rings on the upper end of the shaft. Succeeding rings were put in position by a process of undermining the lower edge of the last ring set, and supported on jack screws until clearance was provided for assembling together the segments of the next ring, which were bolted in position and the process repeated for the successive courses, an operation which was made practicable by the character of the clay encountered and the absence of any serious quantity of water.

In this way the shaft was sunk in about 10 days by an average force of 10 men, including the excavating and lining gangs and their foremen, until it reached the level of the tunnel roof, beyond which the excavation was carried about 20 ft. further, to a depth of about 2 ft. below subgrade, and lined with box cribbing composed of 10x10-in. timbers 13 ft. long, with butt joints at the ends forming a solid rectangular wall. So little water was encountered that it was readily syphoned out of a small sump left for that purpose in the 12-in. concrete floor. Later on a small steam pump was installed which cared for the drainage with little difficulty.

In order to provide clearance for the steel erectors at the anchorage connecting the reinforced concrete tunnel lining with the steel penstock the diameter of the tunnel excavation was made 23 ft. for 50 ft. in from each portal. Between these points it was made with the uniform diameter of 16 ft. to allow for the 13-ft. penstock. The method of excavation in all four headings was the same, differing only in the diameters at the portals and for the intermediate portions of the tunnel. The tunnel was driven entirely in blue clay of medium hardness with both wet and dry places and containing occasional thin seams of sand. It was of marine deposit as indicated by occasional partially fossilized remains.

The excavation was made with a semi-circular top heading 16 ft. in diameter and 8 ft. high, widened out from a drift 18 in. wide and 6 ft. high, advanced 5 ft. at a time, just far enough to set one bent of timbering in advance. This was lined as fast as excavated with 2-in. sheeting boards 5 ft. long and averaging 10 in. in width. In order to clear the reinforcement rings of the lining, 20 in. apart, the spacing of the bents was made a multiple of 20 in., and 60 in. was chosen as the most convenient for the timber ribs, which were made with five 8 x 8-in. spruce segmental timbers, forming a complete semi-arch with the lower ends temporarily supported on 3 x 10-in. longitudinal sill planks. In the enlarged ends of the excavation 10x10-in. segmental timbers were used. The ribs were covered with solid walls and roof of 2-in. lagging or poling boards. Care was taken to extend the heading on both sides to the full width as rapidly as the drift was advanced, allowing the latter to be only one bent ahead of the former, the timbering for each panel being completed before the drift for the next panel was commenced.

The tunnel heading was excavated by the drifting method indicated by the plan diagram, and the numbered transverse sections on the upper line which indicate the respective successive operations. The first operation was the excavation of a center longitudinal drift, on the axis of the tunnel and in the upper part of it, which had a width of about 18 in., a depth of about 6 ft. and a length of 5 ft. The clay was firm enough to stand until this excavation had been made, when a couple of sheeting boards were placed to support the roof and carried temporarily at the forward end of the drift by a cross timber, supported by a temporary center vertical post as shown in Section 1. When this was completed another miner helped the first one and together they widened out the opposite sides of the drift until the first of the permanent arch timbers could be put in position at the outer end and supported by two permanent timbers, the rear ends of the roof boards being always carried by the last completed bent of arch timbering.

Sections Nos. 3, 4 and 5 are symmetrical about their center lines, and No. 3 shows the excavation carried a short distance beyond the vertical post and the roof supported on sheeting boards held in position at the forward end by temporary blocking or struts until another permanent arch timber was put in place, as shown in Section 4. This timber was supported at the lower end by a temporary strut, and by the earth left in its position until the excavation was continued as shown in section 5 and temporary blocking inserted to brace the end of the timber against the first wall board, after which the excavation was completed as indicated by the dotted lines and the final arch timber was inserted and the brace removed.

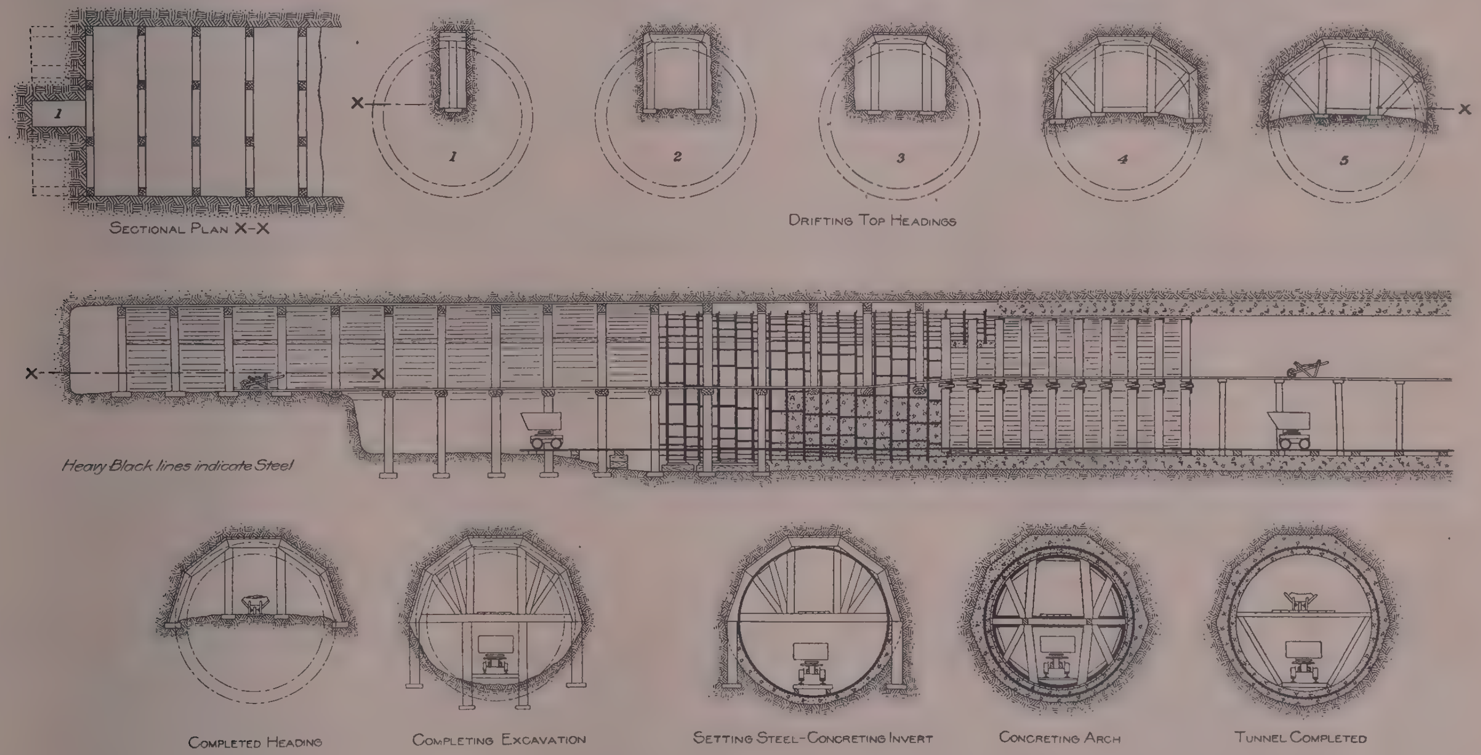
The heading work was done by a maximum force of three miners, two carpenters and two muckers, followed closely by four miners and two carpenters, who set transverse timbers in each bent to carry the vertical posts and excavated the bench down to approximate sub-grade, supporting the arch timbers and transverse beams by vertical posts replaced by longer and longer ones as the excavation was continued.

When the invert concreting work was commenced the intermediate vertical posts were removed, and as the concreting was completed all of the timbering was removed and the concrete packed in over the steel reinforcement close against the surface of the clay. After the invert was concreted the low level surface tracks were laid on transverse timbers, which served as the bottom segments of the inverted arch ribs, with horizontal transverse beams laid across their upper ends to carry the high level surface track.

The excavation was made with slash bars with blades about 4 in. wide, with mattocks, and with spades, at an average rate of about 30 cu. yd. in each heading daily, corresponding to an advance of 5 lin. ft. per day in each heading for two 10-hr. shifts of about 20 men each in each heading, exclusive of 6 timber men in each heading. The clay was shoveled into 1-yd. Koppel end-dump steel cars on a 24-in. industrial track, laid on the tunnel invert at sub-grade. At the lower portal the full cars were pulled up a short stretch of 3 per cent. grade by a ⅝-in. steel cable, operated by a hoisting engine similar to that used for the derrick. At the portal they were dumped into 3-yd. side-dump wooden cars run by gravity about ¼ mile to the spoil bank, and pulled back empty by another cable operated by the same hoisting engine. From the other three headings the cars were pushed by hand to cages in the shaft and at the upper portal. At the top of the shaft they were discharged into dump wagons drawn by one-horse teams, and at the upper portal they were discharged as at the lower portal into dump cars, which were drawn by teams to the spoil bank.

After the completion of the shaft excavation the derrick with which the spoil had been hoisted was put out of commission and its double-drum hoisting engine was utilized for the operation of the twin 4 x 6-ft. cages installed for the tunnel construction. The hoisting lines for these cages were led directly from the head-house timbering to the drums.

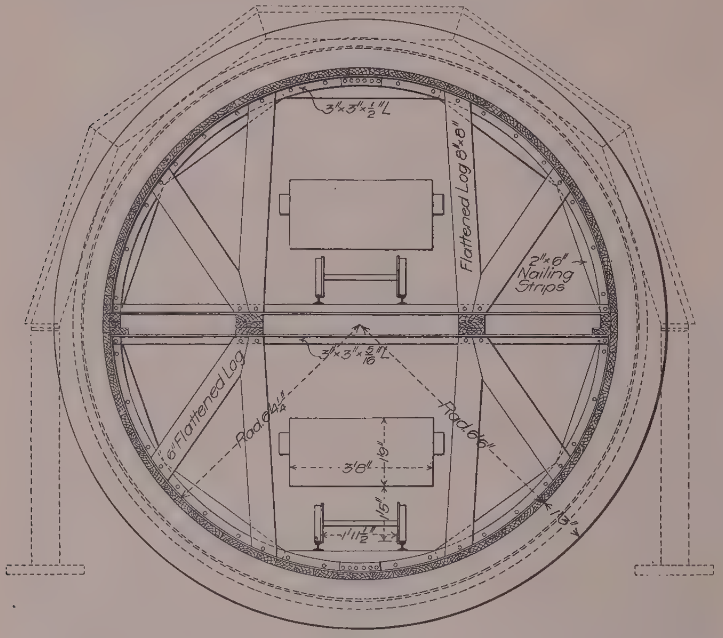
The head-house had a height of about 25 ft. from the surface of the ground, and connected with a two-story frame building about 15 ft. wide and 40 ft. long, having in the upper story two lines of 24-in. tracks from the shaft to the end of the building, on which the muck cars were landed from the shaft. Ordinarily these cars were run to the farther end of the building and dumped over an apron into carts waiting below, which carried the spoil about ¼ mile to a point, where it was used for fill to reinforce the bank between the upper and lower basins. In order to provide for emergencies when the wagon service might be interrupted by holidays, strikes or other unforeseen contingencies, a lateral extension was built to the dump house, extending out over the steep bank of the river and a side track or bypass was laid in it to enable the spoil to be discharged there. The lower story of the building was eventually used for the concrete mixing, but while the excavation was in progress it was generally



Diagrams Showing Successive Steps in the Tunneling Operations.

occupied by the carpenters who used it for cutting and framing the timbering. The building was also extended about 15 ft. on the opposite side of the shaft where the upper story was used for a foreman's headquarters and lunch room and the lower story for storage purposes and as a general assembly room for the laborers, both of them being well heated on account of the low temperature in this latitude.

As this work was executeed between October and April it was exposed to the great severity of the northern winter, and the mercury fell as low as minus 47 Fahr., and for long periods remained from 15 to 20 deg. below zero. Snow also fell to a depth of several feet, and in order to protect the shaft and cut and lower portal they were all enclosed with roofs of 1-in. boards covered with tarred paper and supported on simple timber framing. As the town of Shawinigan Falls has only a population of about 5,000 and a large amount of other construction work was going on at the time the tunnel was built it was necessary for the contractor to provide a camp and commissary for some of the several hundred men employed by him.



Centers for Placing Concrete.

After the timbering was in position and the bench removed, the invert of the tunnel was roughly trimmed to subgrade in lengths of about 15 ft., the reinforcement steel was then assembled resting on the invert, and was jacked up to its proper position and carefully lined about 6 in. above subgrade and the surface of the clay was very carefully trimmed, using the steel reinforcement rings as templates to guide the workmen. Concrete cars were then brought in and the concrete was deposited on the clay up to the springing line, partly covering the steel reinforcement. Afterwards the carpenters immediately followed, setting up the centers and laying the lagging for the invert which was put in position simultaneously with the placing of the concrete up to the springing line. For the invert concrete the cars were run in on the lower track and dumped on the floor of the tunnel and the concrete was shoveled into position as required, and carefully tamped around the reinforcement. For the upper part of the arch ring the concrete was run in on the upper track and dumped on a special platform at the springing level and then shoveled behind the lagging as the latter was carried up to a point about 2 ft. each side of the center, above which it was impossible to shovel it, and it was therefore delivered to the concrete man in small graniteware vessels with riveted handles, which were conveniently passed through the narrow openings between the reinforcement bars. This concrete was made a little stiffer than that for the lower part of the ring, which was quite wet and was, of course, rammed longitudinally instead of transversely.

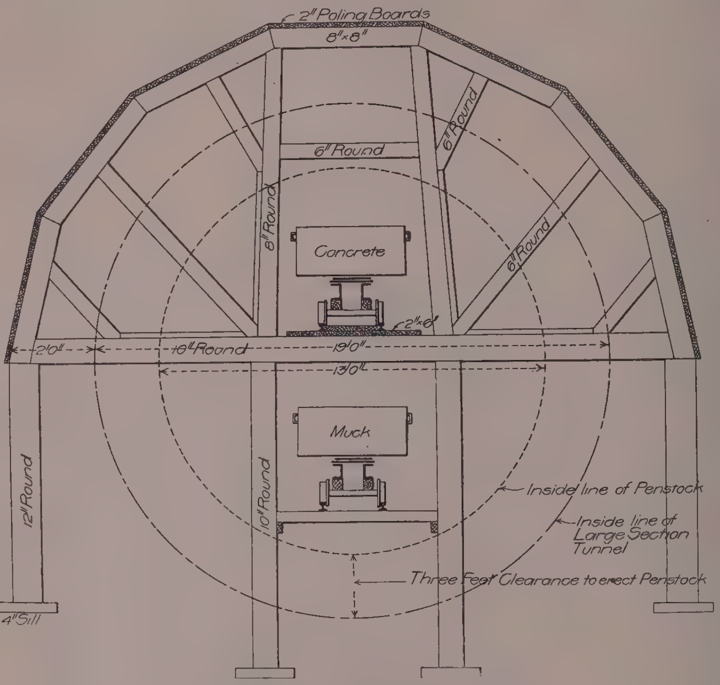
The centering was allowed to remain in position a week or ten days and was then removed to the front end of the concrete, and so on. The concreting gangs were so arranged that work was going on at different parts of the tunnel rings simultaneously; so that the springing line work and centering work would all be in progress at the same time by a total gang of about 50 men in each heading, who finished about 5 lin. ft. of lining per day in each heading. The concreting thus kept exact pace with the headings and excavation and timbering and followed it simultaneously at an interval of about 15 ft. One 7-men erecting gang set the steel for the entire tunnel, moving from heading to heading alternately and thus sufficed for all the concreting gangs, which worked continuously in their different headings.

Segments of the cast-iron lining provided for the old tunnel were assembled together in sets of three transversely and four longitudinally, making arches covering spaces on the surface of the ground about 8 ft. wide and 10 ft. long, in which fires were maintained chiefly with the débris from the tunnel timbering, supplemented when necessary with cord wood. On top of the arches broken stone and sand were piled to a depth of about 1 ft., and were thus thoroughly heated and dried before being wheeled to the mixing platform. The hot stone and sand were hand mixed dry, with the cement and then water, heated by a steam jet in a barrel, was added and thoroughly mixed, after which a jet of live steam was applied to the mass. This resulted in producing concrete at a temperature probably 100 deg. or more, which retained the heat until long after it was placed in the forms and enabled it to set in the coldest weather without difficulty or freezing. No salt was used in the water or cement.

In order to secure lightness, accuracy, ease in assembling and in taking to pieces, facility of handling, durability and interchangeability, special centers for the concreting were made with steel ribs and wooden braces. The upper and lower centers were duplicates and lacked 3 in. each of being full semi-circles. The rib of each was made with a single 3x3x½-in. quadrant angle with two scarf boards permanently bolted to the vertical flange. The splice at the crown was made with a third scarf board and a single steel cover plate on the opposite side bolted to both adjacent quadrants. The ends of the ribs were connected by a 3 x 3 x ½-in. horizontal angle braced to the rib with vertical and diagonal posts bolted at both ends, as indicated in the general elevation.

The scarf boards were made with 2-in. planks and the braces with 8 x 8-in. sawed timbers. The upper and lower centers were separated 6 in. by two sets of 2 x 8-in. horizontal longitudinal planks and double sets of wedges, enabling the upper center to be very easily adjusted and struck. The centers were set 2½ ft. apart midway between the arch timbers and in the planes of the arch timbers and were covered with 2 x 4-in. dressed spruce lagging in 13-ft. lengths with both edges beveled to insure close contact.

Light transverse beams were carried by the longitudinal wedging planks to serve as ties supporting the upper service track, while the lower service track rails were laid directly on the center segments of the lower centers. All timbering in the arch as well as that used for the centers, lagging, etc., was made in short lengths, easily handled by one man and obtainable from the 13-ft. standard lengths, universal in this region for wood which is cut to that length for the pulp mills. Each time that they were used all the members of each center were taken apart and reassembled.

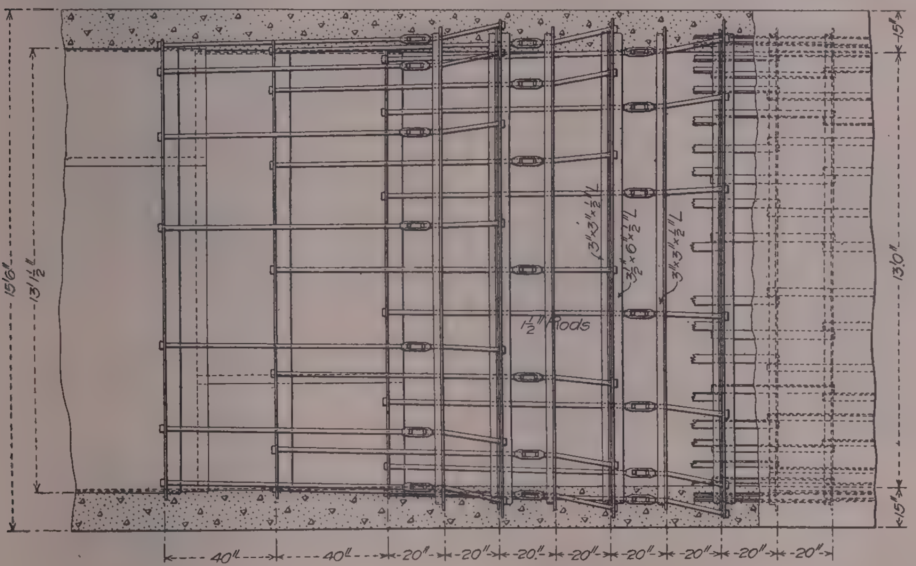


Timbering of Portal Heading.

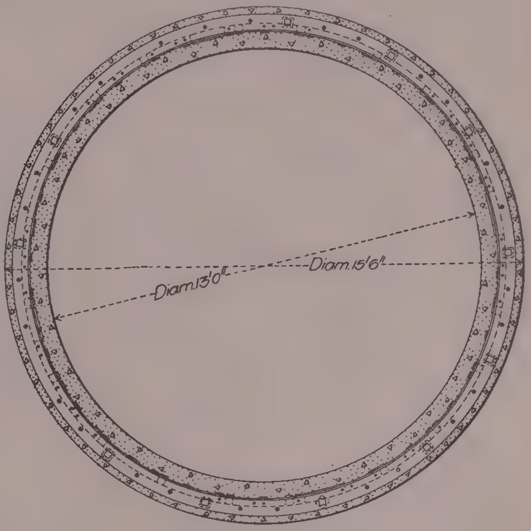
The roof timbering for the enlarged section of the tunnel where the connection was made between the reinforced concrete lining and the steel penstock tube is the same as that already described for the regular 13-ft. excavation except that each rib is made with 7 segmental pieces and that there were 6 diagonal struts and one secondary transverse strut in each bent as indicated in the elevation.

The regular reinforcement for the concrete lining consists of rings 14 ft. in diameter and 20 in. apart, made with single 3 x 3 x 5-16-in. curved angles, connected by horizontal longitudinal 3 x ½-in. bars 5 ft. long and 20 in. apart circumferentially. The angles were cut and bent in quadrants spliced at each joint by an inside cover angle and an outside cover plate, with six bolts on each flange of the angle. The vertical flanges of the angles are turned outward and the 3 x ½-in. tie bars are bent 180 deg. at one end to form hooks engaging the horizontal flange of one ring. At the next ring, the flat bar is bolted to the angle and at the third ring the other end of the flat bar is bent 90 deg., and bolted to the vertical flange of the ring. The ends of successive flat bars are staggered 20 in., so that they are hooked to succeeding rings. All of the reinforcement steel was assembled with ⅝-in. bolts, no rivets being used.

At each anchorage, where the steel penstock joins the reinforced concrete tunnel lining, alternate rings of the latter, three in all, are made special to receive the ends of forty 1½-in. longitudinal anchor rods 10 ft. 1 in. long. Each ring is made with a 6 x 4 x ½-in. and a 3 x 3 x ½-in. circular angle bolted together back to back, with ½-in. washers between. The angles are cut in quadrants spliced with single cover plates 12¼ in. long on each flange and the outstanding 6-in. flange of the 6 x 4-in. angle is punched for the anchor rods clear of the 3-in. ring. The anchor rods are offset 7 11-16-in. at one end by a bend and are adjustable by turnbuckles, the ends being provided with solid heads instead of nuts and screws. They are staggered so that successive lines engage the first, second and third rings respectively at one end and at the opposite end engage three angle iron rings riveted to the exterior of the steel tube 4 ft. apart. These rings are made with 6 x 3½ x ½-in. angles with the 3½-in. flange vertical and punched to receive 14 of the 40 longitudinal rods which terminate there. Notches are cut in the flanges of the two end rings to receive the other longitudinal rods which intersect it but do not terminate on it.



Anchorage of Steel Shell to Concrete Lining.



In addition to the tunnel work, the contractors excavated a trench and built the foundations for the steel penstock. The trench about 20 ft. wide and from 5 to 26 ft. deep was excavated in yellow clay entirely by pick, shovel and wheelbarrow work. It was braced but not close sheeted, and being on a side hill at a very steep inclination did not require pumping. In it concrete piers about 20 ft. long 3 ft. wide and of varying heights were built to receive the cast steel saddles for the penstock. All the concrete for this work was mixed at the portal at the lower end of the tunnel and was delivered by the 1-yd. dump cars running on an industrial track laid in the bottom of the trench over the tops of the piers and dumping in most cases directly into the pier molds. The cars were handled by a cable running over a snatch block at the portal and operated by the hoisting engine. Notwithstanding that the concrete for these piers was laid at a minimum temperature of minus 20 deg. Fah., no difficulty was encountered with it and concrete laid one day was found quite warm the next morning, although protected only by a loose covering of cement bags and boards.

After the completion of the tunnel lining the 3-ft. space around its connections at both ends with the steel penstocks were filled with solid concrete shoveled in and rammed in position. The reinforced concrete lining was then carried across the foot of the shaft, a reinforced concrete manhole shaft 3 ft. in diameter inside was built concentric with the old shaft and the space around it was back-filled with clay from the dump, and the old cast-iron lining rings were successively removed from the bottom upward.

The manhole terminates with a cast-iron cover in the center of the road and about 2 ft. in the clear below the surface of the road, and 10 ft. below the surface of the road a reinforced concrete horizontal tunnel 5 ft. wide and 7 ft. high, protected at the outer end by a suitable gate, was run to the face of the cliff, thus providing an entrance for cleaning or making any repairs or changes that may possibly be required in the future, and also serving as an air vent for the tunnel.

After the completion of the joints between the steel penstock and the tunnel lining, the former in the open cut was surrounded with 2 ft. of concrete, forming a bed on the lower side and a covering on the upper side sufficient to provide for the integrity of the conduit should the steel ever become corroded and disappear. The trench was finally back-filled to the surface, thus completing the work.

As the rigorous conditions of the climate and the isolated position of the work have sometimes cut it off from outside communication for several weeks at a time, it was necessary to lay in stores of supplies and provisions adequate for such a contingency. Broken stone and sand for the concrete were secured near the work and considerable quantities of each were stored under cover at the shaft and at each portal. All of the cement used in the work, aggregating about 10,000 barrels, was delivered in advance and was stored during the winter at the shed erected at the shaft and at both portals. The principal part of this was Iron-clad Portland cement, besides which the Rathbun Star, Intercolonial, White and other Canadian brands were used to some extent.

About 100 tons of 3 x 3 x 5-16-in. steel reinforcement angles in 30-ft. lengths were received from Scotland, by way of Montreal, and were delivered at Shawinigan Falls, where it had been intended to bend and punch them with machinery ordered for that purpose. The bending machine, however, had just broken down under test, and on account of the urgency of the work it was necessary to ship the steel back to Montreal, where it was cut, bent in quadrants and punched for the splices by the John MacDougal Caledonia Iron Works Co., Ltd., and shipped back to the work at Shawinigan Falls, where the remainder of the ¾-in. holes for the connections with the longitudinal reinforcement bars were made with a Doty punch operated by electricity. By this method the holes were punched at about 1-10 cent each, effecting a very large saving o[illegible] the price bid by the Montreal contractor.

In the machine shop at the head of [illegible] there was installed the Doty combined punch and shears, a blower, emery wheel, and a drill press operated by a 50-h.p. Westinghouse motor driven by electricity furnished by the Northern Aluminum Co. In the blacksmith and machine shop the longitudinal 3 x ½-in. reinforcement bars were cut and bent 90 and 180 degrees at opposite ends to engage the circular angles, and were punched to receive the connection bolts. The splice plates and splice angles were also cut and punched at the shop. The 60,000 bolts required for the connections of the reinforcement were purchased from the Gananoque Bolt Co., Ontario, Canada.

The general designs of the work were prepared under the direction of the late Mr. Wallace C. Johnson, Niagara Falls, N. Y., consulting engineer for the Shawinigan Power Co. The work was executed by the Foundation Co., of New York, Mr. Howard J. Cole, superintendent, under the direction of Mr. Edwin F. Fickes, chief engineer of the Northern Aluminum Co. Operations by the contractor were commenced in October, 1906, and completed in the following April, an average force of about 300 men being employed in the daytime and 200 at night.

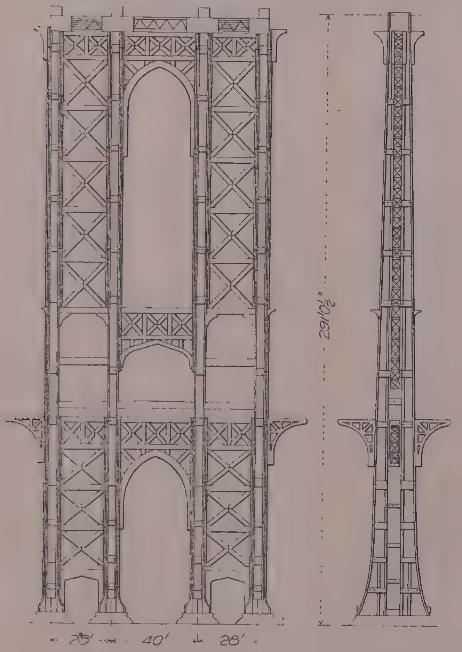
Laboratory Examinations of materials are an important feature in the large German machine shops, according to a report by Capt. G. L. Carden to the U. S. Bureau of Manufactures. At the Ludwig Loewe works, for example, which ships high-grade castings to the United States, the chemical and physical laboratory is quite complete. The German state railways require that for all locomotive cylinders for locomotives a bar shall be cast with the cylinder and of the same metal. This bar must be broken only in the presence of a government inspector, and by him is subjected to physical and chemical test. Not only are the usual physical strains registered, but the bar is shaved and photographs taken under highly magnified conditions of the physical make-up of the metal. The very best thought and attention is devoted to this laboratory work, with the result that Loewe is able to speak advisedly as to the character of the castings. At the Borsig works, similar chemical and physical thoroughness is practiced and in addition all stock is kept under lock and key and issued by storekeepers only on a detailed requisition to avoid using unsuitable materials.

THE ERECTION OF THE MANHATTAN BRIDGE TOWERS.

Among the many important great engineering constructions now being built in New York City is the Manhattan Bridge across the East River between the Brooklyn Bridge and the Williamsburg Bridge. It will afford the first and greatest relief for the extreme congestion which is now so serious a condition of the passenger traffic on all of the different lines of transportation between the boroughs of Manhattan and Brooklyn, and its construction includes the most advanced features of design and fabrication of the steel superstructure and a high development of the methods and plants used for building the substructure and erecting the superstructure, some of which have been described by several articles in these columns. The sub-structure has been entirely completed and work on the superstructure is being pushed rapidly with a view for its completion and the availability of the bridge for regular service at the earliest possible moment to relieve the excessive demands on the other bridges, particularly the Brooklyn Bridge.

The three main spans of the Manhattan Bridge are of the trussed suspension type with a length of nearly 3,000 ft., and a weight of about 42,000 tons between anchorages. The center span, over the channel, has a length of 1,470 ft., from center to center of towers, and a clear height of 135 ft. above mean high tide. It is flanked by two 725-ft. trussed side spans also suspended from the four main cables about 21 in. in diameter as described in The Engineering Record of July 29, 1905. It is 120 ft. wide over all with two decks carrying eight lines of railroad and trolley tracks, two sidewalks and one 35-ft. roadway, and is proportioned for regular and congested live loads of 8,000 lb. and 16,000 lb. per lineal foot respectively, thus giving it, together with the Williamsburg and Blackwell's Island Bridges, far greater magnitude than any other similar structures.

The bridge is notable for the successive changes which have been made in its design since its authorization and for the prominence which was given to the proposal to build it with eyebar suspension chains, for which bids were at one time invited. The structure now being erected will have suspension cables of straight wires of the same type as those in the Brooklyn and Williamsburg Bridges, but will differ from them essentially in the arrangement of the decks, in the type of stiffening trusses and especially in the steel towers about 282 ft. high above the masonry, which weigh about 12,500,000 lb. each, and are made with a comparatively narrow width parallel to the bridge axis and are designed for a fixed bearing for the cables at their top, involving a large bending moment in the tower and a possible maximum lateral displacement or deflection of 2 ft. at the top, although it is expected that this is not likely to actually exceed more than 8 in. in each direction from the center line, under the probable differences in loading and temperature.



Elevations of Towers.

Each tower consists of a single transverse bent with four vertical posts rigidly connected to the masonry and arranged symmetrically in pairs with their centers 20 ft. and 48 ft. from the axis of the bridge. The pair of columns on each side of the center is braced together with transverse and diagonal members from top to bottom, except for an open space of about 44 ft., or 2 panels in height, commencing at the main roadway level where openings are left for the upper and lower double tracks.

Assembling Lower Section of Post.

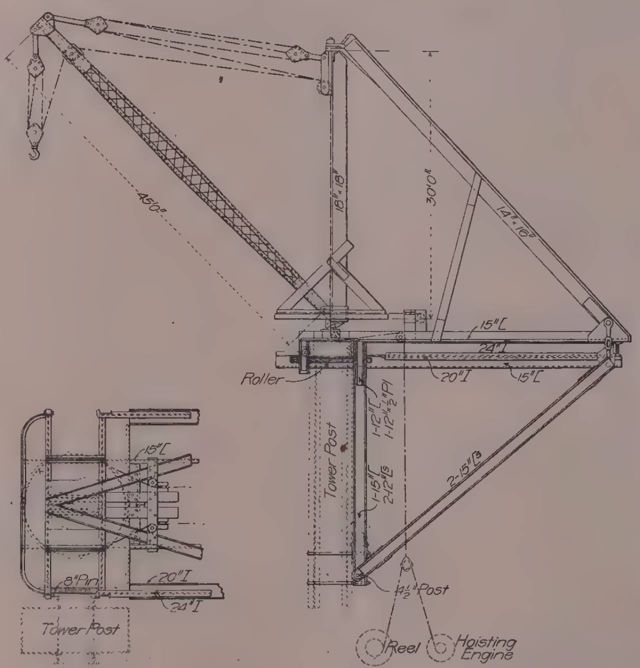
The pairs of columns are braced together across the center line of the bridge by three deep riveted trusses with very stiff curved portal connections below and above the main roadway level and connecting the tops of the towers.

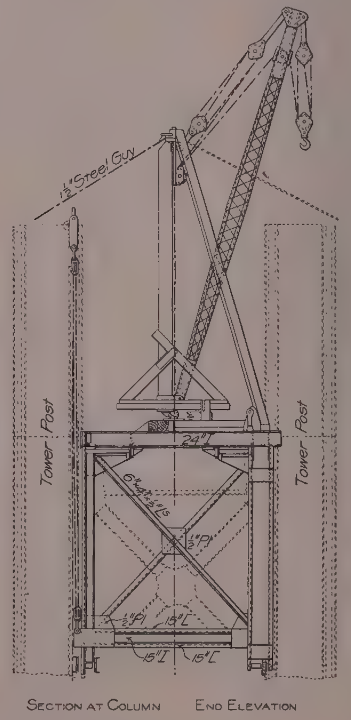
The massive construction of the main columns is almost unprecedented and each of them has a closed rectangular cross section with four interior webs perpendicular to the bridge axis. Their horizontal dimensions vary from 5 x 10 ft. at the top to 12½ ft. wide and 33 ft. long, parallel to the bridge axis, at the base. Each column is made in thirteen sections from about 15 to 24 ft. in length and weighing up to a maximum of 64 tons each. The other members of the towers are correspondingly massive and all have field-riveted connections.

The construction of the columns is special in that the corners are made with double flange angles, inside and outside, with the double web plates riveted between them and they have rectangular extensions in the middles of the long faces giving them a cruciform cross section. The webs are connected at intervals with solid transverse horizontal diaphragms with oval man-holes in the center between each pair of transverse ribs and corresponding iron ladders giving access through the interior to all parts of the column.

The tower piers are of lime-stone and masonry faced with granite and built with pneumatic caissons sunk about 92 ft. below mean high water. The tops of the piers are 68 ft. wide and 134 ft. long with fine cut granite pedestals receiving the four pedestals for each tower. The design and construction of the piers was described and illustrated in The Engineering Record of March 2, 1901, Nov. 29, 1902, and March 12, 1904. The construction of the bridge was authorized in January, 1900, work on the tower foundations was commenced in May, 1901, erection of the steel towers was commenced in July, 1907, and it is estimated that the total cost of the bridge and approaches including land will be nearly $25,000,000, and that it may be open for traffic in 1909.

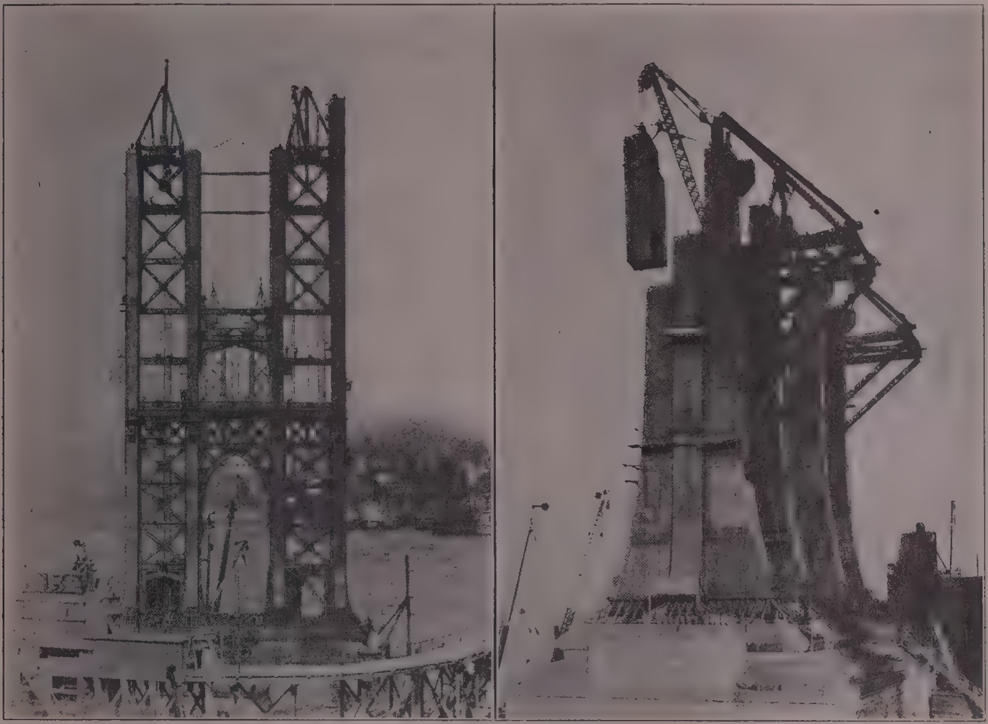
Each of the four tower columns is seated on a separate riveted steel pedestal about 5½ ft. high, 41 ft. long and 22 ft. wide in extreme dimensions, which weighs about 380,000 lb., and is designed to distribute a maximum vertical load of nearly 21,000,000 lb. over 695 sq. ft. of pier masonry. It is anchored by eight 2¾-in. anchor bolts, threaded their whole length, and grouted 11 ft. deep in the pier masonry to resist a maximum uplift of 334,000 lb. Each pedestal has main vertical webs in the planes of those of the columns and additional diagonal webs distributing the great load over the heavy base plates. It





Tower Traveler for Erecting the Manhattan Bridge Towers.

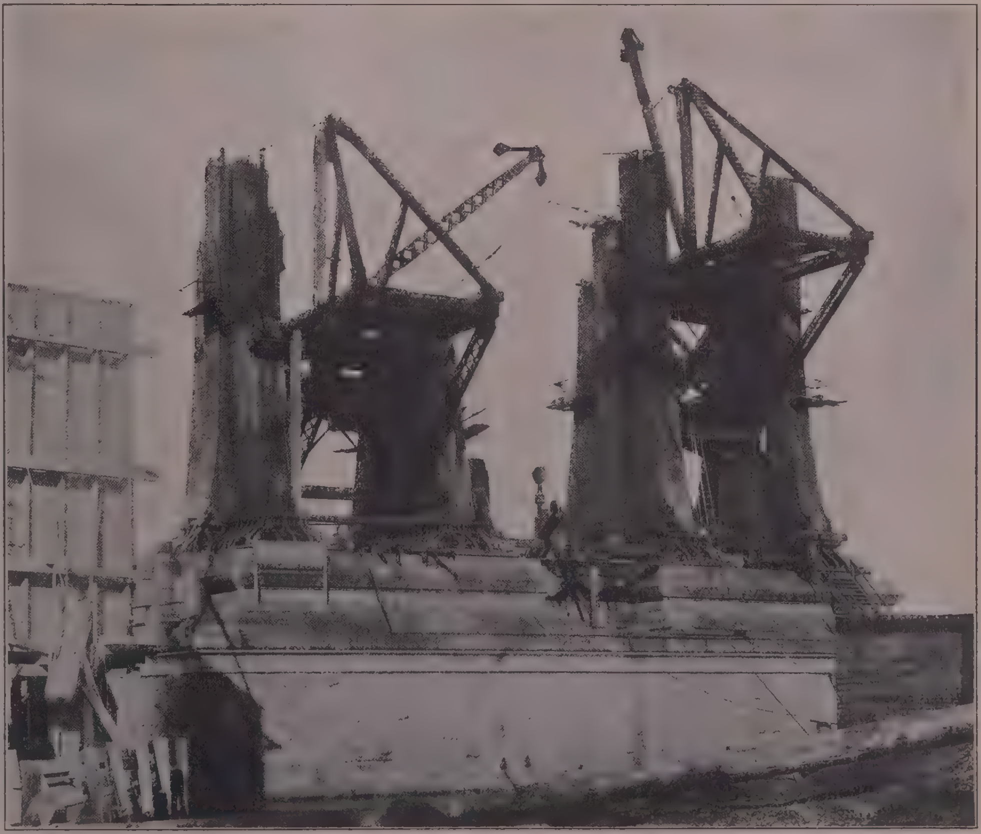
is made in six sections, of a maximum weight of 80,000 lb. each, which are fastened together by horizontal bolts through the vertical transverse webs and are spliced to the column webs with vertical splice plates on both sides. The general appearance and the weight of the pedestals correspond to the cast-steel construction which was at first proposed, and their interesting details are illustrated in The Engineering Record of Oct. 19, 1907.


Brooklyn Towers of the Manhattan Bridge on Nov. 13 and Dec. 21, 1907.

The large cut stones forming the tops of the piers were carefully set with their upper surfaces about ¾ in. above the required level and transverse and longitudinal lines 3 or 4 ft. apart were laid out on them and scored by hand with great accuracy to the exact level, as checked by instruments. Pneumatic tools were then used to cut down the squares between the scored lines and the surface was verified and recut and again leveled, showing the exact height in most places and only very slight inaccuracies in other places. Finally the surface was redressed by hand, making a very smooth true plane on which the pedestals are seated without grouting or the interposition of any intermediate diaphragms or fillers.

The sections of the pedestal were delivered by lighters and lifted by their derricks to the tops of the piers. About forty 2-in. cast-steel balls were placed on the fixed masonry bed plates which receive and help to splice together the sections of the pedestals and on them the heavy pedestals were easily rolled to position after which they were jacked up, the balls released and the jacks slacked off to lower them to their final position. The 40-ton lower sections of the columns were also erected by the lighter derricks and a guyed wooden derrick with a 60-ft. boom of 10-tons capacity was set up on the pier between the tower columns and erected the travelers for handling the remainder of the steel in the tower. These travelers are of novel construction moving upwards as the erection progresses and are operated by hoisting engines permanently located on the docks on the shore sides of the piers.

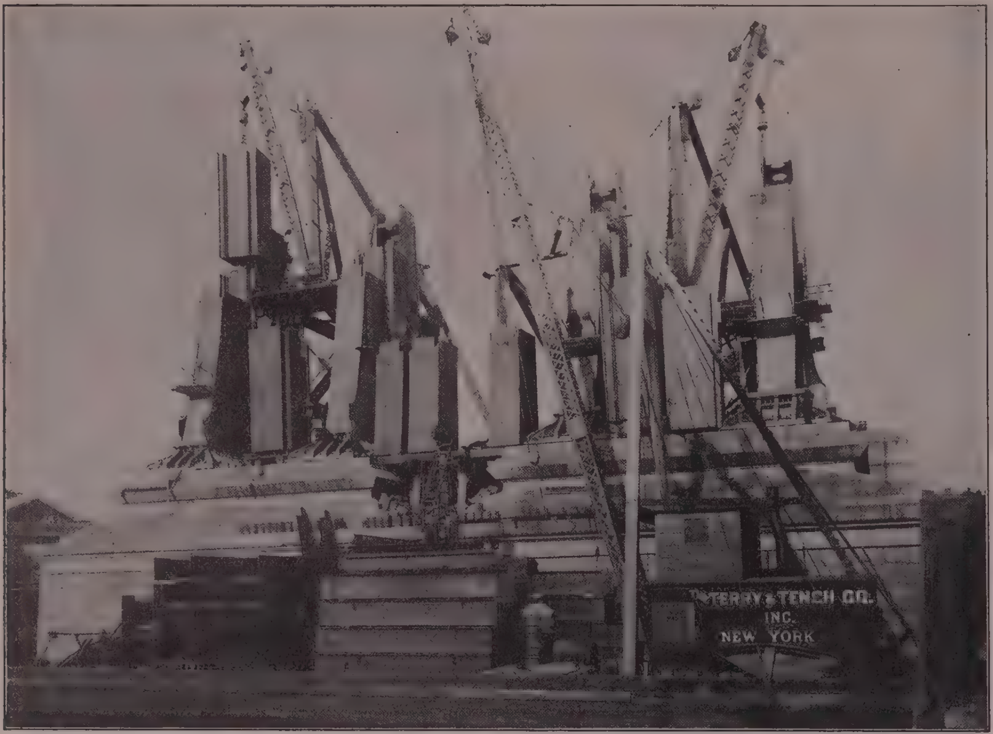
There are in all four duplicate travelers, two for each tower, each traveler erecting two main columns and their proportion of the transverse bracing. Each traveler is essentially a stiff-leg boom derrick seated on a steel cantilever bracket attached to the two main columns and moving up on them as they advance. The bracket is made entirely of steel with a 21 x 34-ft. horizontal platform projecting from the shore face of the tower and carried by a vertical transverse bent about 25 ft. high in the plane of the tower, and two pin-connected inclined struts from the foot of the bent to the outer extremity of the platform, completing with it triangular trusses calculated to sustain a total load of 260,000 lb. for each traveler. The brackets are attached to the columns by riveted yokes at the platform level which enclose the columns and are provided with horizontal friction rollers bearing on all four faces of the columns. The feet of the posts in the vertical bents are clamped to the column posts with pairs of screw end U-bars. The horizontal platform is built with 20 and 24-in. I-beams with riveted gusset plate connections and has special framing and solid horizontal web plates between the tower columns projecting to their river face to receive the derrick mast.


Travelers in First and Second Positions, New York Pier.

The derrick is of standard type with wooden mast, stiff-legs and sills and a 45-ft. steel boom, both provided with special and standard Terry fittings. In the lower part of the tower the traveler was guided by the rectangular projections on the longitudinal faces of the tower columns and in the upper part of the tower where these projections disappear, temporary 16-in. vertical timbers were bolted to the face of the columns to serve the same purpose for sections 6 and 7.

The traveler complete with its equipment has an estimated weight of about 130,000 lb., but as the center of gravity is not far outside the tower, the bending moment in the latter is comparatively small and is far within its strength and the stability afforded by its weight and anchorage.

The stiff-legs of the derrick are fastened to the sills with pairs of ½-in. connection plates bored to receive pin-connections for vertical anchor bars connecting them directly through the inclined struts in the brackets and adjustable by sleeve nuts. The derrick boom is made with a pair of 15-in. 40-lb. channels, latticed on both flanges and bent to taper from 6 in. at the point to 24 in. at the center between webs. At both ends the lattice bars are replaced by long ½-in. cover plates reinforced and bored to receive the axles of the sheaves and the shackles for the tackles. Solid transverse diaphragm plates are inserted both sides of the middle to stiffen the boom and its cross sectional area of 22½ sq. in. is calculated to be efficient for a compression stress of 188,000 lb. For 35-ton loads the hoisting tackle is rove with 10 parts of ¾-in. steel cable and for 50-ton loads is rove with 14-parts. The topping lift is correspondingly rove with 14 and 18 parts of ¾-in. line passing through special blocks with 6-in. sheaves. The boom is swung with a steel bull wheel operated by ⅝-in. line from auxiliary drums on the hoisting engine which, together with the lead lines from the foot of the mast for the main tackles, are carried down vertically to the pier masonry and thence around snatch blocks to the hoisting engine. When in service the top of the mast is guyed transversely by two 1½-in. lines connected to open holes in the splices at the upper ends of the column sections. For hoisting the 64-ton maximum column sections extra sheaves were rigged outside the regular blocks allowing the number of parts in the hoisting and topping lift tackles to be increased to 16 and 20 parts respectively by engaging the bights of the line in the sheaves without unreeving the main tackles.



Lighter Delivering Materials to Travelers, Manhattan Bridge.

The steel is delivered from the storage yard at Bergen Point by lighters and unloaded by their derricks to two large storage scows moored to each of the piers which are commanded by the traveler derrick that hoists the material as required for erection. During the month of February, when only 16 days were available for working, over 2,000 tons of steel were erected.

As the tower is erected the traveler is hoisted from story to story by two tackles each rove with 13-parts of 1½-in. Manila line and shackled to the feet of the vertical posts and to very heavy plate links with hooks engaging the upper ends of the last column sections erected. Both tackles are rove with a single continuous line, one end of which is carried to one hoisting engine and the other end to the other hoisting engine, thus securing their combined power and equalizing their action so that the estimated load of about 55 tons is raised 25 ft. in two or three minutes.

A solid steel pin 9 in. in diameter and 9 ft. long is placed transversely under the end of the horizontal platform girder and supported on brackets attached to the vertical posts of the traveler. When the traveler is hoisted to the required position these pins are rolled out to the face of the tower columns just above the pairs of heavy gusset plate which form jaws for the tower bracing and the hoisting tackles are slacked off a little to allow the pins to take bearing on the plates adjacent to the flanges of the tower columns and thus receive the weight of the traveler which is further secured by screwing up the yoke clamps at the feet of the vertical posts.

The hoisting tackles are then lifted by the traveler boom, disengaged from the tower columns, and stored on the traveler platform until required for hoisting the traveler another story when they are replaced by the derrick and the operations repeated. The connection plates on which the traveler is supported are always reinforced by wooden fillers bolted between them before the traveler is seated on them. In the case of the two highest stories of the tower the derrick could not command the column sections when seated directly on the connection plates and special supports were built up 5 ft. above them to receive it and give it the necessary height.

Very convenient platforms for field riveting are made with riveted frames of light steel bars and angles to which the floor planks are bolted and which are suspended by inclined rods from the open holes left for field rivets in the splices above. The frames are provided with sets of upper horizontal cross bars on which planks may be laid for temporary scaffolds but which are not allowed to be used for regular riveting. The men are required to continually maintain a safety railing around the scaffold. Enough of these scaffolds are provided to enclose the three outer faces of each tower column and thus provide a continuous platform around it at each working level, but in practice they are not continually maintained in the same horizontal plane. They are handled by the traveler derrick and enable the fitting and riveting to be carried on very advantageously. Substantial stairs with hand rails are provided which are carried up as fast as the erection of the tower progresses and promote the safety and convenience of the men besides saving considerable time.

A duplicate plant is provided on each side of the river and comprises at each tower two travelers, two special Lidgerwood hoisting engines, a stiff-leg derrick on the pier and two adjacent storage scows and on shore a power plant equipped with two 50-hp. horizontal boilers, one of them provided with a steam turbine blower for forced draft, one Ingersoll-Sargeant air compressor and 30 pneumatic hammers. At present there are six riveting gangs on each tower and each gang is supplied with a Chicago pneumatic forge for heating the rivets. About 200 men are employed on both sides of the river and on the New York side the tower had been erected up to the 11th story and about 11,000 tons of the steel were in position March 1, when the work was almost as far advanced on the Brooklyn side.

The bridge is designed and constructed under the direction of the Department of Bridges, New York City, Mr. James W. Stevenson, commissioner, and Mr. C. M. Ingersoll, chief engineer; Mr. Alexander Johnson, consulting engineer; Mr. D. E. Baxter, assistant engineer in charge of construction, and Mr. A. I. Perry, assistant engineer in charge of design.

The travelers were designed by Mr. Terry, and were built in the shops of the Terry & Tench Co., at 131st Street and Lexington Avenue, New York. Mr. Wade Cline has had charge of the erection under Mr. Terry.

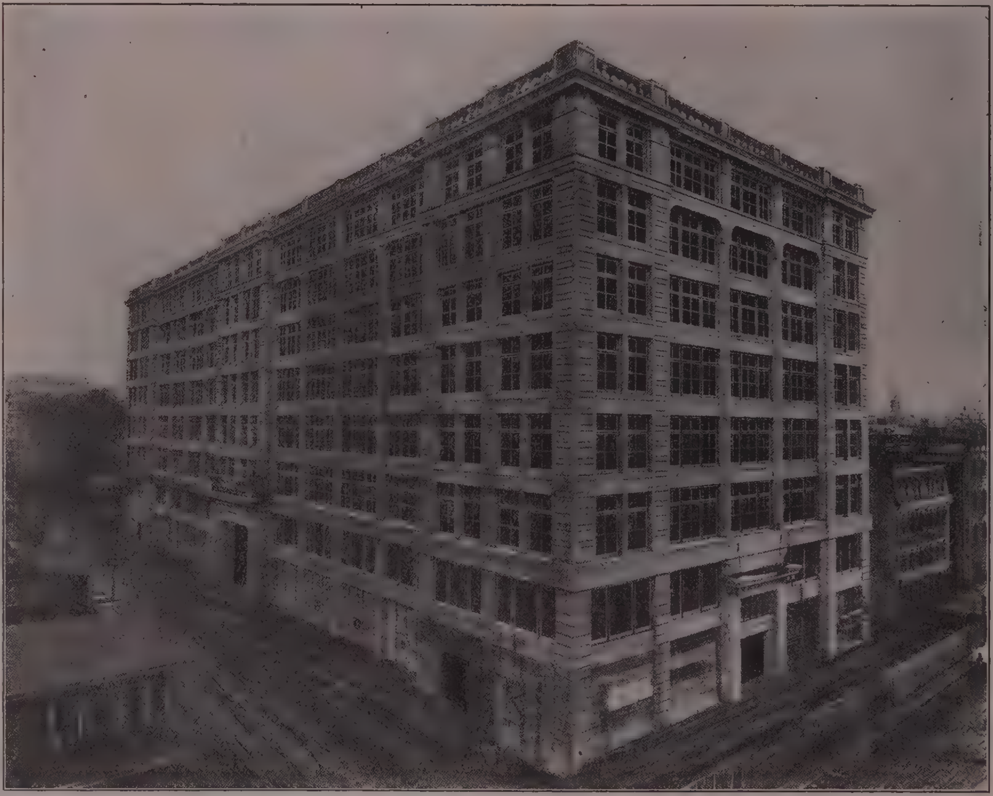


Fig. 1. General Appearance of the Phelps Publishing Building.

The New Building of the Phelps Publishing Company.

On Jan. 28, 1906, the extensive plant of the Phelps Publishing Co., at Springfield, Mass., was entirely destroyed by fire. This property embraced some ten buildings of from one to five stories in height, originally intended for various purposes, situated in the heart of the City. In the publishing business, perhaps more than in any other, an interruption of business means great loss, so the work of temporarily caring for the various Phelps publications, numbering a dozen or more, was arranged before the ruins were cold. At the same time, also, plans were laid for a thoroughly up-to-date office and publishing building to take care of this vast business. Reinforced concrete was decided upon, after a thorough investigation of various types of construction, because it offered the most economical style of construction, and on account of its fireproof qualities, cleanliness, rapidity of erection, and the security against vibration, due to printing machinery, afforded by its monolithic construction.

The architect recommended also that the exterior was be constructed in reinforced concrete. It will be noticed that his design is simple in outline, without elaborate detail, but sufficiently varied by recessed portions, belt courses, and other features to form an effective building. The cornice and balustrade are also in concrete. The great advantage gained in having exterior walls of concrete is seen in the exceptionally wide windows and narrow piers, thus making it possible to omit the usual hollow square in the center of a building 100 ft. in depth.

The windows are 17 ft. wide with 3-ft. piers. Approximately 80 per cent of the exterior wall surface is in windows, and thus every portion of the building is thoroughly lighted. The average height of the windows is 9 ft. and to facilitate lighting the center of the building the architect has employed his usual method of placing the interior lintels 10 in. below the bottom of the slab and changing the beam and girder framing at the end sections to give the same result, thus eliminating one of the common constructive features, viz., the passing of beams by the windows or the lowering of the window lintels to permit it.

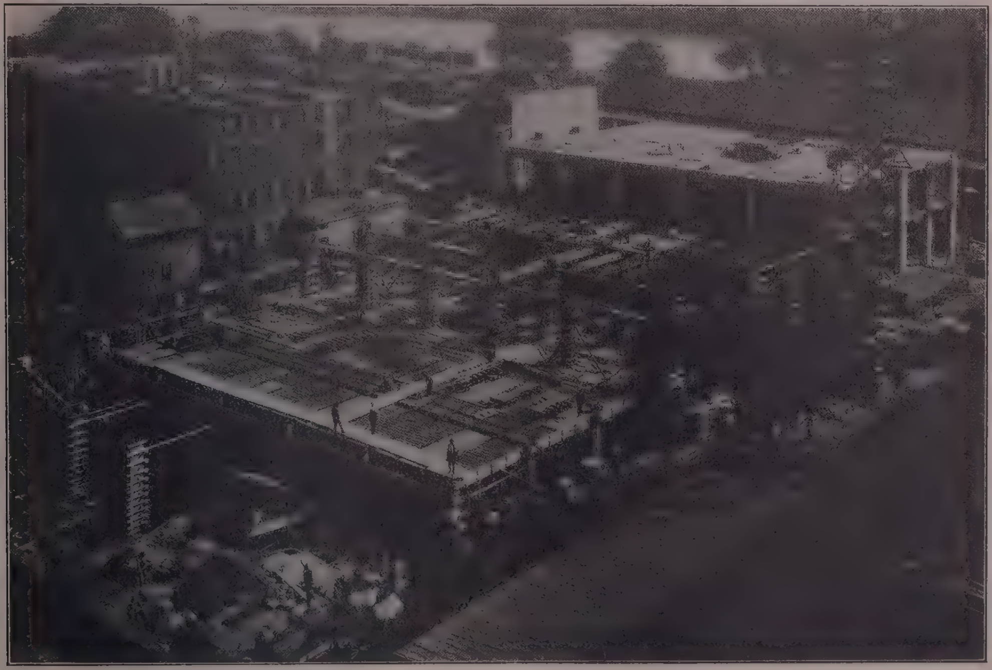


Fig. 3. General View of Building during Construction.

The building is nine stories and basement in height, 125 ft. above curb, the ninth story being above and back of the cornice lines, and 105 x 285 ft. in plan or an area of nearly 30,000 sq. ft.

to the floor. The interior columns are octagonal in section up to the seventh story where the section was made a square. In decreasing the size of the columns in the successive stories a unique feature was introduced which resulted in considerable saving. The reduction in column area was accomplished without changing the width of the four main faces of the octagon from its original 12 in. This made the changing of the column forms much simpler than is ordinarily the case.

The foundation soil is sand figured at a safe load of 3 tons per square foot. Spread footings were used. The floors were designed for live loads of 200 lb. per square foot and the roof to carry 100 lb. per square foot. This latter loading was used to take care of several special structures, such as a photograph gallery, a dining hall, etc., which were called for on the roof beside the usual pent houses. The floor slabs are 4½ in. thick with 1-in. granolithic finish put down by acid bond after the main construction was completed.

One of the accompanying cuts gives a good idea of the exterior appearance of this building. Though not yet washed down with the finish wash, the façade presents a pleasing effect. The ornamental balustrade parapet and railing over the main doorway, which were cast inside the building and set by doweling, are about 5 ft. high and while simple in detail add greatly to the building. The amount of detail on this exterior is unusual in concrete buildings and not only presented some interesting problems in form work, but also was very costly owing to the number of different kinds of columns.

Access is afforded to the six Otis plunger elevators with which the building is equipped by entrances, three in number, one on each of the street fronts. The main entrance on Worthington St., being about 22 ft. wide by 20 ft. high presented a unique problem in structural design in reinforced concrete. One of the illustrations shows the forms with the reinforcing steel in place, for the girder which spanned this doorway. The exterior column in the center of the building, six stories in height, is carried by this big girder. The tremendous load concentrated on the middle of the girder develops excessive shear stresses and made the reinforcement exceedingly heavy and complex.

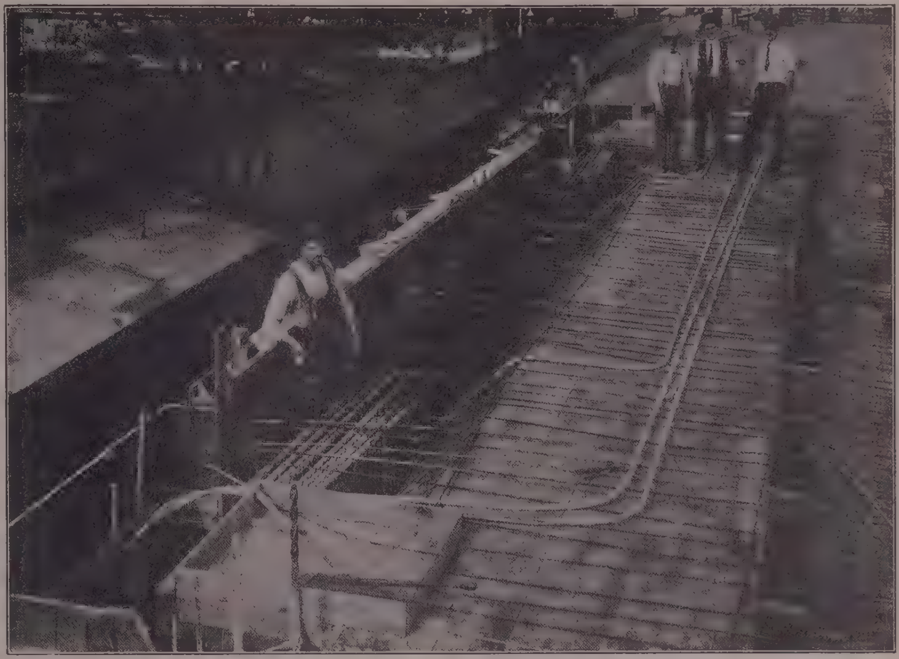


Fig. 2. Reinforcement of Girder over Main Entrance.

The elevators and the stairways, of which latter there are four, of reinforced concrete with metal treads, are enclosed throughout the building by reinforced concrete partitions 4 in. in thickness, and all doorways are provided with automatic fire-doors, the sills of which are raised 1 in above the normal floor level to prevent flooding of the lower floors in case of fire or accidental opening of the sprinklers. There are scuppers in the rear curtain walls which will allow accumulated water to run off in such a contingency.

The building is to be heated by the Sturtevant blower system through flues under the basement floor to vertical flues, those on the rear being run inside the concrete columns, thus saving valuable floor space. The fresh air is drawn from 125 ft. above the street. Electric current for lighting and power will be furnished by a plant in the basement and distributed through conduits laid in the concrete floor slabs. To provide for the wires, holes were left in the beams and girders. To take care of the piping and shafting, cast-iron spool hangers were set in the concrete slabs flush with the ceiling. All pipe risers are carried in a central vertical shaft and a dust chute takes care of rubbish from the floors. This dust chute reduces the fire hazard greatly and by depositing all the débris of the building in an air-tight chamber makes the structure an extraordinarily clean one. The building is being equipped with all the modern office building devices for commercial service. The plumbing is to be of the best, and will be installed by Donahue Bros., of Springfield.

The power plant in rear of the basement is to have a capacity of 1500 h.p. The first installation comprises two 250-hp. Atlas water-tube boilers, with necessary accessories and machinery. To provide for this the besement is in three levels, with 10 ft. difference in elevation between the lowest and the main level. In connection with the power plant there is a Weber reinforced concrete chimney 150 ft. high.

Although the actual work of construction began June 4, 1907, owing to the delay occasioned by allowing the ruins of the old press building in the center of the lot (which was flooded at the time of the fire to save the presses) to remain until a sufficient portion of the new building had been erected to allow the removal of the presses to it, it was not until Aug. 18 that the entire lot was turned over to the contractor. The operation of the presses was not for a single moment interfered with. The progress of the construction of the floors and walls after the whole building was under way was at about the rate of a floor every 9 days, five floors, however, being run up in 31 days. Column forms were constructed for an entire floor and for four bays additional and slab and beam forms for a floor and a third. The roof was laid on Nov. 1. The presses were moved into one portion of the building before the rest of the structure could proceed. The first press was in operation before the next was moved.

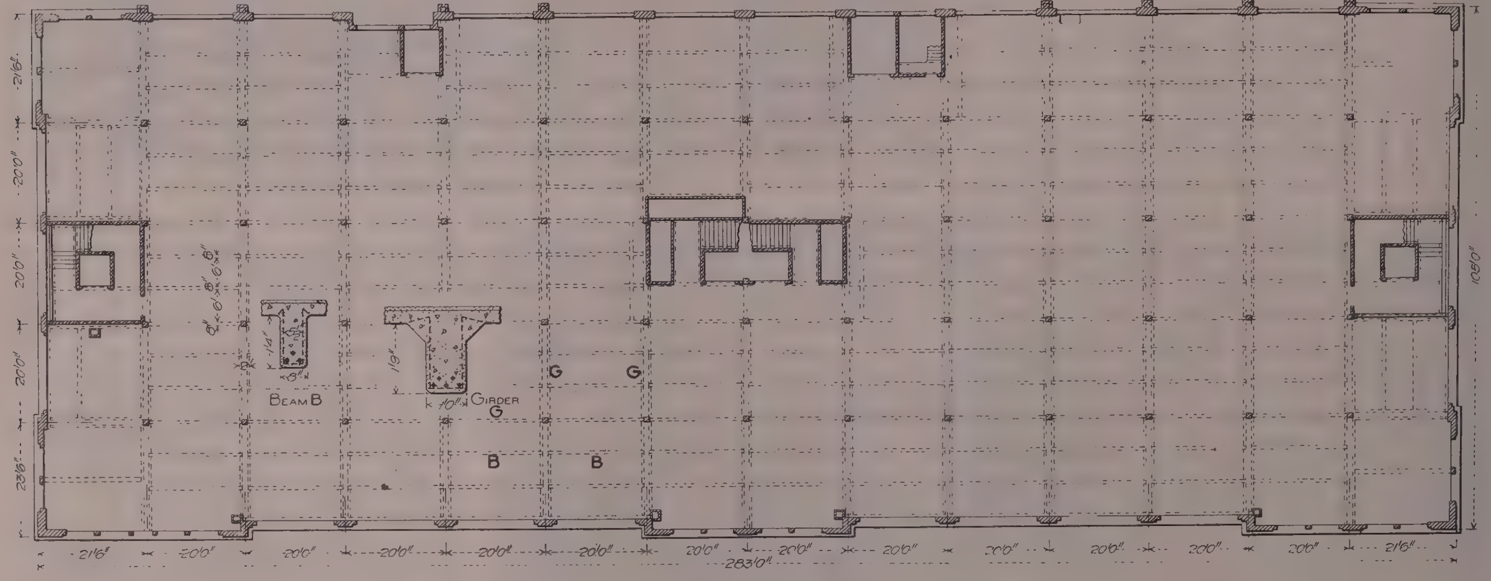


Fig. 5. Typical Floor Plan, Showing Column and Beam Spacing.

The general layout of the plant is shown in Fig. 3. Some of the spiral column reinforcement may be seen and the lower section of the floor at about the center of the picture, has the reinforcement laid ready for concreting. The plank runaways were laid and men were clearing out the beams getting ready for the concrete when this picture was taken. The way the forms were erected is illustrated in the work under way at the center of the building.

The mixing plant consisted of one No. 3 Ransome mixer with regular Ransome bucket, box, and hoist. Power for this mixing plant was furnished by a 40-h.p. motor belted to the mixer and hoisting drum.

The concrete for slabs, beams and girders was a 1:2 1/2:4 mix and for the columns 1:2:3. The reinforcement consisted of Ransome cold twisted steel except in the columns where the vertical bars were round steel, made continuous by pipe couplings, and spiral hooping of heavy steel wire. Cement storage was provided in a shed on the street and the cement was delivered by tracks and dumped into the basement through holes in the first floor, close to the mixer. All steel was stored and fabricated on the 1st floor. Forms and steel were hoisted to place by three portable power-driven cranes which were lifted from story to story as the work progressed.

In the setting of the 250-h.p. boilers it was found necessary to go deeper with the ash pits than was originally intended. This brought them into water and also endangered the footings as sand boiled up from under them when within 10 in. of their bottoms. To overcome the problem of excavating and close sheeting and in order to get a bed for the waterproofing in the bottom of these pits, "boats" of 1/8-in. sheet lead were built to the exact shape of the pits and enough larger to allow for a concrete lining. These lead tanks, weighing about 1500 lb. each, were constructed on ways, and launched and floated into place like any boat. By this method greater speed was made and the work done at less cost and danger than by using the felt waterproofing employed in the balance of the basement floor, where an elaborate system of tile-drains was provided and connected with an automatic pump, adjusted to operate when the water level rose within 6 in of the top waterproofing. A cross-section of these lead boiler pits is shown in Fig. 4.

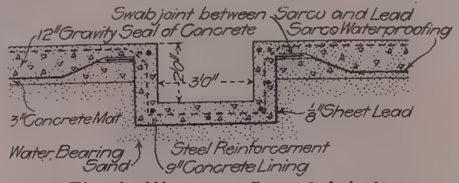


Fig. 4. Waterproofing of Ashpit.

Much credit is due the construction company for its careful system and the rapidity with which it has executed this extensive building, which is throughout an exceptionally fine piece of concrete work. Mr. F. S. Hinds, of Boston, was the architect and engineer, and Mr. J. A. Cole, the supervisor for the architect and owner. The Turner Construction Co., of New York, was the contractor, and Mr. A. C. Tozzer was its superintendent. Mr. Herbert Myrick is president of the Phelps Publishing Co., Mr. George T. Gilbert is its chief engineer and Mr. F. G. Smith is its superintendent.

Hollow Concrete Blocks are coming into use at penitentiaries, for it is found that their manufacture can be carried on successfully by prisoners under careful supervision. Several buildings have been erected at the New York City reformatory on Hart's Island, with blocks made on a Hercules machine, which is also used at West Rutland, Mass., and Jamesville, N. Y., prisons.

A Clay Cofferdam.

The Chambal bridge on the Nagda-Muttra State Ry. near Kotah, India, has sixteen short spans with masonry piers carried through wet shingle, sand, boulders and disintegrated rock to solid rock at a maximum depth of 27 ft. below ground-water line. The method adopted for excluding the ground water from the treacherous excavation was primitive and costly in labor, but, according to a recent article in "Indian Engineering," was successful. It was better adapted to localities where labor is very cheap, timber and steel expensive, engineering plant difficult to obtain and time of secondary importance than it would be under ordinary circumstances.

The pier site was at first enclosed with trenches having an average width of 14 ft. at the top, 4 ft. at the bottom and an average depth of 14 ft. They were excavated in successive lengths of 50 ft. with continuous pumping, any intermission in which caused the sides to fall in. As fast as excavated the trenches were filled with clay brought from the adjacent river bank. After the completion of this cofferdam a concentric interior pit was excavated with dimensions from 30 to 40 ft. less than the corresponding inner faces of the cofferdam, thus leaving an embankment 15 or 20 ft. wide, protecting the inner faces of the cofferdam and balancing the exterior earth pressure. The faces of these banks were sloped somewhat and were protected by a revetment of gunny bags filled with clay without which the face of the excavation kept falling off. The cofferdams proved so efficient that a single 7-in. steam-driven centrifugal pump sufficed to drain two or three pits and the work was successfully carried through the entire season. Materials for two wooden cofferdams were kept on hand for emergency, but were not needed and eventually were used for derricks and other purposes.

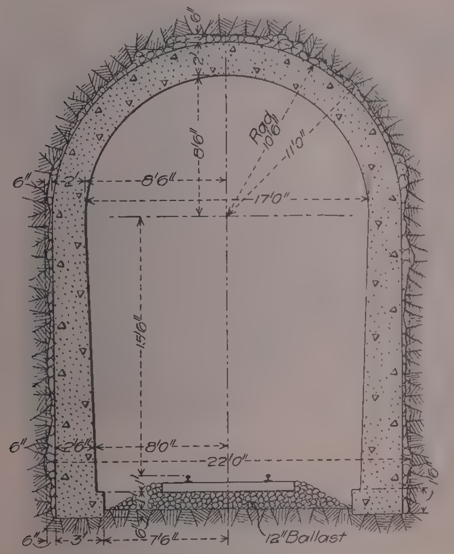
The article does not give details of the method of executing this work, but the engravings accompanying it show pits apparently 20 or 30 ft. deep with the upper parts of the sides sloped about 1:1 and the lower parts much steeper and lined with clay bags. No derricks or other plant are visible, but inclined planes are trenched down into the pit and sloping wooden platforms extend from the top of the clay bag walls to the bottom of the pit for the accommodation of natives carrying out the excavated material in baskets on their heads. Such a method of construction is only advisable, of course, under exceptional conditions, where it is difficult to obtain power, although it is hard to understand why such facilities could not be furnished in the same way as the steel plate bridge girders.

The Second Raton Hill Tunnel of the Atchison, Topeka & Santa Fe Railway.

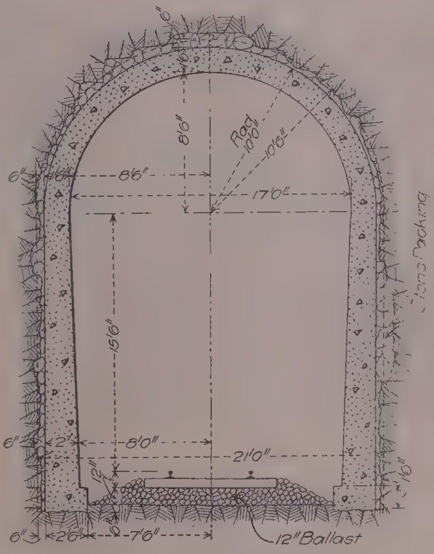
The highest point on the main line of the Atchison, Topeka & Santa Fé Ry. is at Raton Pass, on the state line between Colorado and New Mexico, where an elevation of 7,608 ft. above sea level is reached. The steep grades required to ascend to the pass from both sides present a very great handicap in hauling the tremendous volumn of through traffic that is carried over this railroad. The main line of the latter through Kansas and Colorado rises gradually on an almost continuous ascent for 570 miles from Kansas City, at an elevation of 750 ft. above sea level, to La Junta, Colo., at an elevation of 4,054 ft. above that level. From La Junta to Trinidad, Colo., the rise is more pronounced, an ascent of 1,927 ft. being made in a distance of 81.5 miles. Trinidad is only 15 miles by the railroad from Raton Pass, but the difference in elevation between the two is about 1,600 ft., the tracks rising on a practically uninterrupted grade between the two points. The first ten miles of this ascent is less abrupt than the remainder, as a grade of 184 ft. to the mile is maintained in the last five miles. The rise required to reach the pass from the west is about 7 miles long and involves an ascent of 991 ft., although steep grades occur for some 10 miles farther.

When the line was first built through Raton Pass it crossed the latter on a switchback. The cut through which a section of this switchback was laid is shown in an accompanying illustration, from which the rugged character of the country in the locality may be seen. The switchback was replaced about 30 years ago by a single-track tunnel 2037.5 ft. in length, which was built with the summit of the grade over the pass at its west portal. This old tunnel still remains in service, carrying all of the main-line traffic. The construction of a second tunnel to relieve it was started last April, however, and it is expected this second tunnel will be finished early in 1908.

West Portal of New Tunnel.



Section in Soft Material.



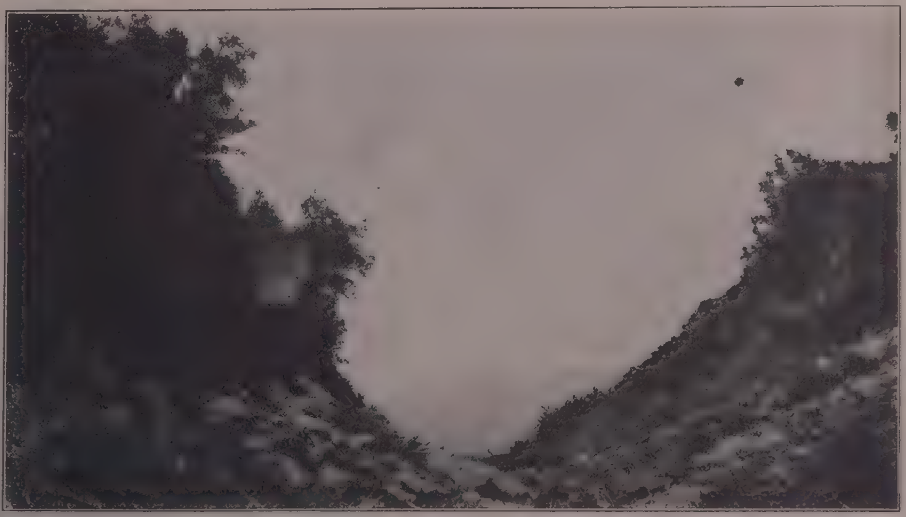
Section in Loose Material.

The completion of this tunnel will not only relieve the congestion of traffic on the main line of the Atchinson, Topeka & Santa Fé Ry., but with other improvements that have been made, or that are under way, will greatly increase the capacity of that system for handling transcontinental business. Chief among these other improvements are the Belen-Texico cut-off in New Mexico and the reconstruction of the existing line through northwestern Texas, Oklahoma and Kansas. The Belen-Texico cut-off extends from the main line at Rio Puerco, just west of the central part of New Mexico, to Texico, on the state line between New Mexico and Texas, where it connects with the existing line across Texas, Oklahoma and Kansas. This cut-off, which is nearly ready for operation, has a total length of 270 miles. When it is opened for traffic it will permit all of the present mountain grades in New Mexico and Colorado, between Albuquerque and Trinidad, to be eliminated by the traffic over it.

The reconstruction in Texas, Oklahoma and Kansas is a part of the grade reduction and realignment work which is under way from Winslow, Ariz., to Chicago, a distance of 1,630 miles. A large part of this work has been finished and much of the remainder is in progress. When the present plans for changes between Winslow, Ariz., and Chicago are carried out, the maximum grade in this distance will be 0.8 per cent., which occurs in Missouri, while outside of that state the maximum grade will be 0.6 per cent. This remarkably low-grade line will enable a great volume of new business to be handled, and will also permit much of the traffic over the present main line via Raton Pass to be diverted over the second main line to be created by the Belen-Texico cut-off. At the same time, the second tunnel through Raton Pass is more than justified by the reasonably certain increase in traffic in the local region through which the present main line passes, and by the great saving in operating expenses which it will permit to be made.

Some years prior to the inception of the construction of the second tunnel at Raton Pass the line on the sides of the ascent to the pass had been double-tracked and entirely rebuilt. Most of the existing steel bridges and wooden trestles were replaced by stone masonry arches. A few heavy plate-girder spans, designed to carry modern train loadings, were provided, though, in places where masonry structures could not be built readily. The curves on the heavy grades were all carefully lined, and on maximum grades were provided with compensation. Irregularity in the grades was also eliminated as fully as possible. The tracks are laid with 85-lb. rails, with tie plates on all curves, and are ballasted with crushed rock. Notwithstanding this high-grade construction, the nature and volume of the traffic over the pass renders the maintenance of tracks a very serious matter. The heaviest engines on the entire system, and some of the heaviest engines that have been built, are used on the operating division in which Raton Pass is included. Every train that goes over the pass has from one to three heavy engines as helpers, with the result that on the unusually heavy grades the track is subjected to great wear.

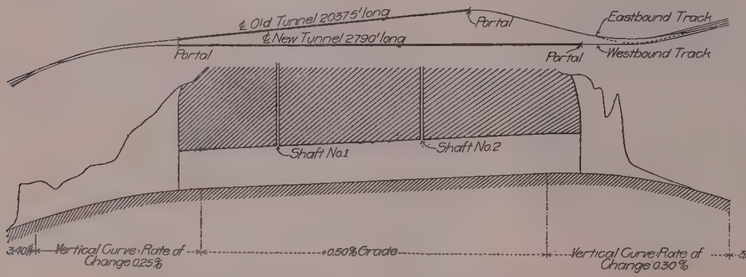
The new tunnel will be 2,790 ft. in length from portal to portal and will be used for westbound traffic, the old tunnel being reserved for eastbound traffic. The two tunnels are entirely separate, but are close together. Their east portals start at the same point, and at these portals their



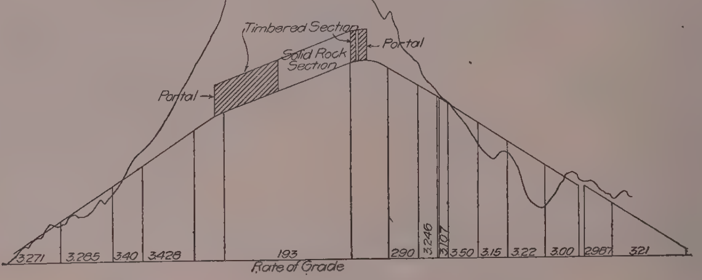
Summit Cut of Original Switchback.

center lines are 40 ft. apart. Both tunnels are on tangent for their entire length, their center lines making an angle of about 5½ deg., so at the west portal of the old tunnel they are 238 ft apart, although the west portal of the new tunnel is 752.5 ft. beyond that point. The present track curves around the hill at the west end of the old tunnel and 800 ft. beyond the west portal of the new tunnel joins the track that will be laid through the latter.

The old tunnel for practically its entire length is built on an ascending westbound grade of 1.93 per cent. A vertical curve connects this grade at the east end with the steeper ascending grade on that side, and a second vertical curve at the west portal connects it with the descending westbound grade at that end. At present the helper engines on the westbound trains are thus required to pass through the tunnel before they can be cut off, resulting in a serious operating condition. This condition will be eliminated by the grades of the new tunnel, when the latter is opened for westbound traffic. The grade in this tunnel also has its summit at the west portal, but it is all on only a 0.5 per cent. rise westbound, with a long vertical curve at each end connecting it with the descending grades in both directions. A single engine can therefore readily handle a train in either direction through the tunnel, thus permitting the helper engines to be cut off before trains enter either portal.

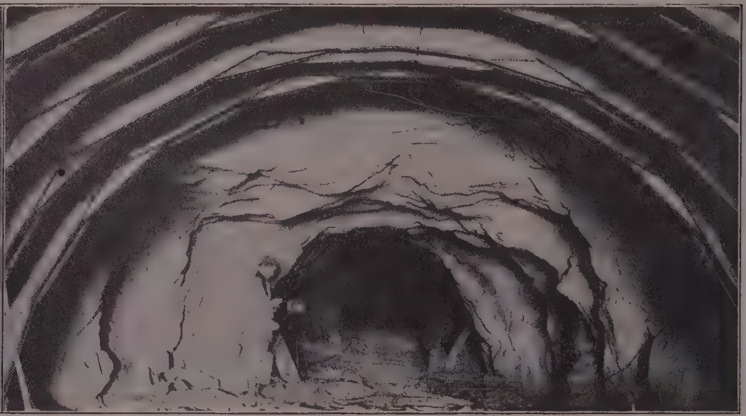


Plan of Both Tunnels and Profile of New Tunnel.



Profile of Old Tunnel and Track on Either Side.

East Portals of Old and New Tunnels.



Heading and Timbering in New Tunnel.

The new tunnel is to have a cross-section of unusual size, as may be seen from one of the accompanying illustrations, and is to be lined from portal to portal with concrete. Part of the tunnel is through loose material and the balance through rock, some of which stands without timbering. The old tunnel is through practically the same material and is only timbered for about half of its length, part of the timbering being at each end. Experience with falls in the unlined solid-rock section of this tunnel, however, has led to the decision to line the new tunnel throughout. The clear height inside the lining will be 24 ft. above the top of the rail, at the center line of the arch, and the clear width at the springing line of the arch, 17 ft.

In driving the new tunnel through soft material the excavation is made to a minimum width of 22 ft. and a minimum height of 29 ft. at the center line. In such material the side walls of the concrete lining have a footing course 3 ft. wide and 1.5 ft. high, the rear of which is flush with the rear face of the wall. The latter varies in thickness from 2.5 ft. at the base to 2 ft. at the springing line of the arch, the rear face being vertical and the front face battered 6 in. in 16.5 ft. The arch ring also has a thickness of 2 ft. Where loose material and rock are encountered the tunnel is driven to a minimum width of 21 ft. and a clear height of 28.5 ft. at the center line. The side walls of the lining in such material have a 1.5x2.5-ft. footing course, are 2 ft. thick at the base and 1.5 ft. thick at the springing line of the arch; the ring of the latter is 1.5 ft. thick. These various dimensions of the concrete lining are for minimum sections. The irregularities between the excavation and the outside limits of the concrete are filled with loose stone packing, laid by hand.

Very little water was encountered in driving the tunnel, so no special provisions had to be made to carry away the seepage. Such inflow as does occur, however, will be taken to the east portal by a gutter formed in the top of the footing courses of the walls.

Refuge bays for watchmen and trackmen working in the tunnel are provided at intervals of 232 ft. These bays are to be placed alternately on both sides of the tunnel. They are simply arched openings 5 ft. wide and 7.5 ft. high at the center, in the side walls. Three larger openings for placing small push cars are to be built in the side walls. These openings are 8 ft. wide and 12 ft. high at the center, and are spaced 696.5 ft. apart.

Construction Plant and Methods.—The tunnel headings were driven from both ends and from two construction shafts, making six points from which they were advanced. A central power plant set up about 1,000 ft. from west portal, furnished air for operations in the headings. This plant contained two 100-hp. return tubular boilers, a type W B 2 Sullivan air compressor, with a capacity for supplying eighteen 3½-in. piston drills, and two 25-kw. 125-volt generators, both driven by a 90-hp. Armington & Sims engine. A 4-in. air line 3,200 ft. long was laid from a 4½x12-ft. receiver at the plant, over the hill through which the tunnel was driven, to the east one of the two shafts, and thence continued as a 2½-in. line to the east portal. A 2-in. branch was taken from this 4-in. line at both of the shafts and carried down the latter to the face of the excavation in the headings; connections were also carried to the working face of the headings driven from the portals. Wires were strung from the power plant to all parts of the work, in order that electric lights might be provided as desired.

Both construction shafts were built 5 ft. 8 in. by 10 ft. in cross-section, one being 109 ft. and the other 115 ft. in depth to the crown of the tunnel arch. One shaft was placed 1,100 ft. from the west portal and the other 700 ft. from the east portal. A cage hoist was installed in both shafts, a Lidgerwood hoisting engine operating one and a Mundy hoisting engine the other. Steam for both of these engines was supplied by a 100-h.p. boiler set up between the two. The material removed from the headings carried forward from the shafts was hoisted to the surface in 1½-yd. dump cars and wasted in adjacent spoil banks.

An approach cut containing about 40,000 cu. yd. had to be made at the east portal, and one of 20,000 cu. yd. at the west portal. The east cut was made partially in earth and partially in rock and was taken out by hand, the material being hauled away in dump cars. The west cut was largely in rock and was made with a steam shovel.

The heading driven from the west portal was put through as far as the first shaft with a section smaller than that of the arch section of the tunnel, and was then enlarged later. For the first 800 ft. from the west portal the excavation was in rock down to the springing lines of the arch, with coal and shale formations below the rock. Accordingly, no timbering was required for that distance. In the balance of the tunnel, however, the headings were all timbered as the work progressed. This timbering has ribs, each built of four 3x10-in. plank and spaced 3 ft. apart on centers, with 2x12-in. plank for lagging.

About 75 per cent. of the blast holes in the headings were made with Jeffrey rotary drills equipped with augers. Twenty-two of these machines were installed and gave good satisfaction in making holes in the material encountered. They were also operated at a considerable saving of power as compared with piston drills. For the remainder of the work, which was mostly in rock, eight 3½-in. Sullivan piston drills were used.

After the heading from the west portal and one of those from the west shaft had met, work was started at the west portal on the removal of the bench. A Model 20 Marion steam shovel, working on compressed air, was installed in the west end of the tunnel to be used in removing the bench cut, which was taken out in one lift. This shovel took out 1,300 linear feet of the bench, involving over 18,000 cu. yd. of material, in three months. It was then moved to the east portal and started on the bench cut at the end. Meanwhile the bench adjacent to the west construction shaft, starting at the point where the shovel was taken out, is being removed and loaded into cars by hand, which are taken up the shaft to be dumped. The west 1,100 ft. of the tunnel has thus been finished ready for the concrete lining, work on which can be carried on without interference from the unfinished portion of the tunnel excavation.

A concrete mixing plant has been set up on one side of the west portal approach cut where rock can be obtained readily for the concrete. A Symons crusher has been installed just above the mixing plant and delivers to a storage bin over the latter. The concrete will be made in a ¾-yd. Ransome mixer, which is set on a tower built over the service tracks leading into the tunnel, so concrete can be dumped directly into cars on those tracks. The equipment to be used in placing the concrete in the tunnel lining forms has not been completed, but will consist of a working platform mounted on cars.

Work on the tunnel has been carried ahead very rapidly in spite of numerous handicaps. The construction camp was established March 22 last; work was started on the construction shafts April 10 and completed May 15; the west portal heading was started May 10 and the other five on May 25, but owing to the scarcity of labor only the portal headings were carried on continuously. The first two headings met July 10, the second two Aug. 6 and the last two Sept. 9. The removal of the bench was about 55 per cent. completed on Nov. 1 and should be finished by Jan. 1.

Reconstruction of Old Tunnel.—After the new tunnel has been finished so traffic can be diverted through it, the old tunnel will very probably be enlarged to the same section as the new one and lined from portal to portal with concrete. At present 840 ft. of the old tunnel is timbered, the clearances in this section being a width of 14 ft. and a height of 18 ft. 4 in. at the center line. The remainder of the tunnel is unlined and is 14 ft. 8 in. wide by 21 ft. 3 in. in height at the center line. The proposed increase in section would in both cases mean the removal of nearly as much material as has already been taken out, although the present sections could be made to fit the new section practically without loss.

The plans for the new tunnel were prepared under the direction of Mr. C. A. Morse, chief engineer of the Atchison, Topeka & Santa Fé Ry., and the construction work is being prosecuted under his supervision by the Lantry Construction Co. Mr. Jos. Weidel is engineer in charge of the construction work for the railroad company.

Underpinning Bridge Column Foundations in Philadelphia.

Market Street, is carried over 30th Street, Philadelphia, on a 3-span deck girder bridge with a buckle plate floor and longitudinal girders supported on the abutment walls and on two transverse bents on the curb lines. Each bent has 6 riveted steel columns about 14 ft. high, web-connected to a line of transverse plate girders about 3 ft. deep and 20 ft. long which thus virtually form continuous girders extending across the full width of the bridge. The columns have riveted extended bases at curb level seated on masonry piers carried down about 6 ft. below the surface and supported by piles capped with a timber grillage.

The recent construction of the elevated railroad on Market Street necessitated the erection of four of its columns at this point where they pass through the floor of the 30th Street bridge to independent foundations in the bed of 30th Street and are so close to the columns of the latter that it was found necessary to underpin the old columns before building the foundations for the new ones. This was effected without serious obstruction to 30th Street and without in any way interfering with the superstructure of the old bridge or the very heavy and continuous traffic across it.

Underpinning Bridge Column Foundations, Showing the Use of Three and of Two Cribs.

The work was executed by a simple system of cribbing and jackscrews arranged somewhat differently at different columns. In one case timber cribs about 8 ft. high and 16 ft. apart in the clear were built on opposite sides of the column to be supported, on the center line of the transverse girder, and on them were placed eight 12 x 12-in. timbers about 30 ft. long, arranged in two tiers to make four compound 12 x 24-in. girders, two on each side of the columns. Short cross timbers were placed close together on the tops of these girders and wedged to bearing against the bottom flange of the transverse girder except at the center, close to the column, on both sides of which they were replaced by short rails.

A similar but lower pier was built enclosing the column, and clearance was left above it to receive twenty-four 10-ton jackscrews in four transverse rows reacting against four lines of 12 x 12-in. cross pieces engaging the lower side of the compound girders. When the jack screws were operated their force was applied directly to the column and the girder connection until they took the entire load at this point and raised the whole structure slightly so that the column was suspended from its connections independent of its foundations. The ends of the compound girders were then wedged tightly on the tops of the cribs, the jacks were slacked off and released and the center crib was removed leaving clearance between the end cribs for the excavation and construction of the new foundations.

At one of the other columns the ends of the girders connected to it were temporarily carried on twelve short lengths of heavy horizontal T-rails placed on opposite sides of the columns close to it and engaging the lower flanges of the main girders. The rails were alternately placed right side up and bottom side up, on opposite sides of the columns close to it, so as to pack as closely together as possible, and were supported on a set of four 20-in. I-beams 25 ft. long, two on each side of the column close to it. The I-beams had a clear span of about 15 ft., and were seated at each end on two transverse 12 x 12-in. timbers about 8 ft. long and 3 ft. apart on centers. Each timber was supported on six 10-ton jack screws set on a cribbing of 12 x 12-in. timbers making piers about 8 ft. square at the base, 7 ft. high and 15 ft. apart in the clear. Between them 12 x 10-ft. pits were sheeted down 8 to 19 ft. to a firm subgrade for the new foundation. This method was somewhat more convenient than the one first described because it obviated the use of the center pier, thus saving some time and labor but on the other hand it required heavier jacking and involved the use of the long and heavy I-beams of which the supply was not sufficient to provide for the underpinning of all the columns simultaneously.

Four of the columns supporting the old bridge floor were underpinned by a force of 8 men in about 10 working days. It was estimated that the maximum load carried by each column is 82 tons. The work was done under the direction of the Engineering Department, of the Philadelphia Rapid Transit Co., Mr. W. S. Twining, chief engineer; Mr. Chas. M. Mills, principal assistant engineer, and Mr. Frank R. Fisher, resident engineer. These foundations were comprised in the contract with McGraw & Grey for the elevated railroad foundations, the larger part of the underpinning described being done by Sheeler & Sons.

BRIQUETTES were used for fuel to the extent of 44,000 tons by the Austrian State Railroads last year, according to a Consular Report. About one fourth of these came from England and cost about $5.80 per ton, and the remainder from Pilsen, Bohemia, at $3.60 per ton. Some of the briquettes weighed 2.2 lb. and some 4.4 lb. each.

Progress on the Bridge Loop Subway.

Section 2 of the Bridge Loop of the New York system of subways has about 1,300 ft. of 4-track subway in Center St., and 1,300 ft. of 2-track subway in Canal St. Nearly all of it was originally designed to be of standard reinforced concrete construction with rectangular cross section and details corresponding to those of other sections of the subway which have from time to time been described in these columns. Ordinarily the roof was to be a continuous slab of concrete divided into transverse spans not exceeding 15 ft. by, and supported on, the sidewalls and intermediate longitudinal rows of rectangular reinforced concrete columns 5 ft. apart on centers. Where heavy loads are to be carried on the roof the latter was to be made with flat concrete arches supported by 15-in. transverse I-beams 5 ft. apart.

The construction was to be very irregular on account of depressed tracks, crossovers, a Y-shape connection with the branch of the new Manhattan Bridge and great variations of levels were necessitated by a maximum grade of over 4 per cent. Where the outside tracks descended below the center tracks there was to be a gradual change of cross-section which involved a large amount of special construction.

The contract was awarded on this design, plant was installed, construction methods developed, and the excavation well advanced when, very recently, radical changes were made in the design, the low level tracks were eliminated, maximum grades and depths of excavation reduced and all four tracks located at the same elevation in Center St. The construction has been changed to steel frame for all the Center St. section and for a block on Canal St. between Mott and Elizabeth Streets where provision is made for crossovers between existing and future tracks; the rest of the Canal St. section remains reinforced concrete.

The difficulties and the cost of the construction are increased not only by its irregularities but by the heavy traffic which must be maintained unobstructed in the narrow street above, by the large quantity of underground pipes, conduits and other structures in service above and below its roof, the treacherous nature of the soil and the ground water encountered in some places and the heavy adjacent buildings with shallow foundations, whose stability is endangered by the subway excavation.

The subway interfered with a large brick sewer in Center St., with a large number of pipes and conduits, with two lines of pneumatic postal tubes, with gas and water mains and intersected a number of vault and cellar walls.

One of the first operations was the commencement, last June, of a by-pass sewer 7 ft. in diameter in adjacent streets which has been connected at both ends to the old sewer and has just been put in service to care for all but local drainage and enable the intermediate portion of the old sewer to be cut out and abandoned before subway construction is commenced so that when it is encountered in the excavation it can be removed without further trouble. Similarly parallel lines were laid for some of the most important gas and water mains, gates and valves were inserted and the service was shifted to them to enable the old pipes to be removed as the excavation proceeded. In other cases the pipes and conduits were supported in their original positions where they were clear of the subway roof or were moved horizontally and vertically to clear it when practicable and carried on temporary supports until they can be permanently seated on the finished roof.

The 6-in. pneumatic tubes must be maintained in constant service except for a very brief interval in the early morning and as it is necessary to preserve their perfect alignment and air-tightness it was thought to be impossible to maintain their integrity and shift them back and forth and they were therefore replaced for the contractor, by new parallel lines laid on Park and Mulberry Streets by the pneumatic company, and put in service last December.

For one section the original sewer which was located on the line of the subway is replaced by two parallel new sewers just outside the subway wall which are constructed in advance in sections of convenient lengths as the excavation progresses and the service diverted to them, forming by-passes as successive corresponding portions of the old sewer are demolished.

The double-track structure in Canal St. is about 30 ft. wide and 20 ft. high over all with the roof at a maximum depth of about 12 ft. below the pavement and involves an excavation of about 40 cu. yd. and the placing of about 8.36 cu. yd. of concrete and 416 lb. of steel per lineal foot. Ground water line varies from 25 to 35 ft. below the pavements and is not encountered between Baxter St. and Brooklyn Bridge. The soil consists of earth, clay, gravel, sand and quicksand with some boulders.

In order to prosecute the work uninterruptedly, avoid obstructing the street, diminish the danger of accidents and reduce the cost of watchmen, it was decided to build the section entirely in a completely covered trench. The details and methods of this form of construction have been so efficiently developed that the work is now progressing steadily without any interruption to traffic and very few indications visible in the street to suggest the magnitude of the work being carried on below the surface.

Elevated Platform for Hoisting, Storage and Loading.

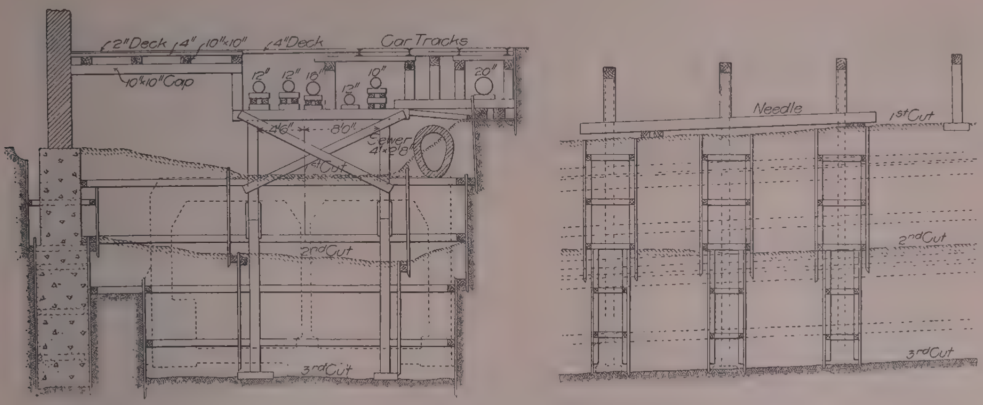
The excavation has a depth of 25 to 30 ft., a width of 30 to 60 ft., and occupies everywhere the full space between curbs and sometimes extends beyond the vault walls or to the foundations of adjacent buildings. Operations were commenced by removing both by day and by night half-width sections of the pavements up to about 100 ft. long, after which shallow longitudinal trenches were immediately dug to receive continuous lines of 10 x 10-in. stringers 6 ft. apart. These were immediately covered with a deck of 4-in. transverse planks replacing the pavement from curb to curb and permitting traffic to be maintained uninterruptedly over it during the progress of excavation and construction below it. This deck has been laid for the full length of the section on Canal St., and for about ¾ of the Center St. section, and three approximately equidistant pairs of 6 x 20-ft. shafts have been sheeted down to sub-grade close to the curb.

From each shaft the excavation has been made in both directions and in several steps. It has been carried on by two radically different methods, both of them having, however, the same first operation. This consists in the making of a full-width first cut from 8 to 12 ft. deep which is carried down to about the level of the footings of the front walls of most of the adjacent buildings and is sheeted, when it does not extend to the building or vault walls, with 2-in. square edge planks driven with mauls as the excavation progresses.

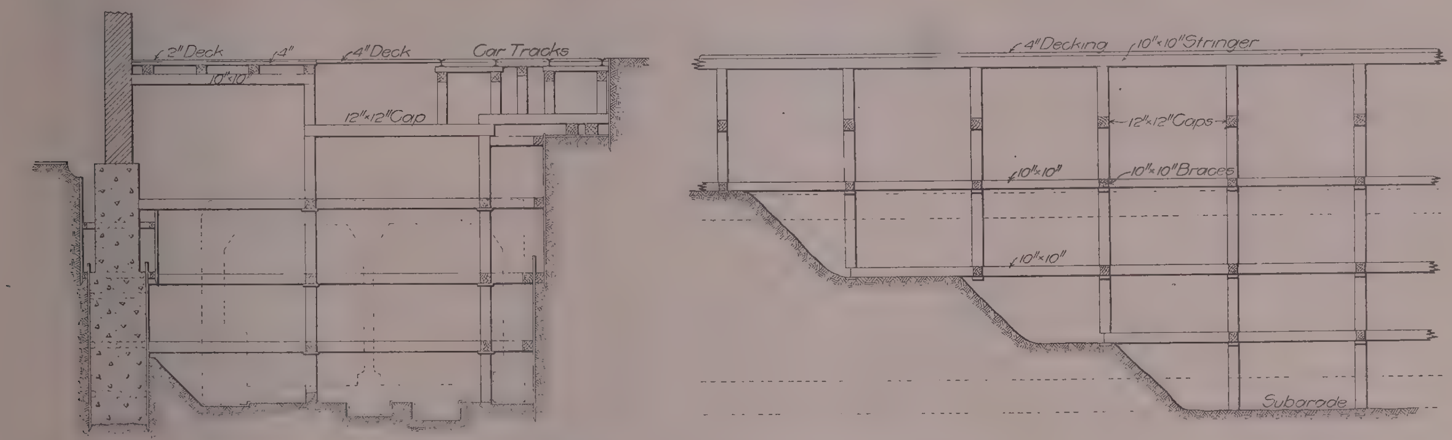
As fast as the earth is removed 10 x 10-in. transverse caps are placed under the longitudinal stringers about 10 ft. apart and are carried at first on blocking which is replaced with vertical shores, for which longer and longer lengths are substituted as the excavation progresses until full-length pieces reaching to the bottom of the first cut are seated temporarily on horizontal planks. Care is taken to locate them intermediately between the subway bents so as to provide the maximum clearance for that structure, and their length is always such so as to bring their feet several feet above the tops of the finished subway roofs.

A 10 x 12-in. stringer under each rail supports the ties for the trolley tracks and is carried by vertical posts on intermediate 12 x 12-in. caps about 6 ft. below the street which at one end extend beyond the subway wall and are supported by longitudinal sleepers laid on a berm at the side of the main excavation. The pipes and conduits encountered which do not have to be removed, are carefully blocked, wedged or chained to the transverse timber so as to be firmly supported without danger of displacement or settlement. Whenever the pipes or sewers are to be displaced laterally the new ones are built parallel to them in the required position outside the subway limits, connections are made and the old ones are abandoned and removed, or when practicable with the pipes in service, they are gradually removed a short distance vertically or horizontally to give the required clearance and permit the remainder of the excavation and the construction of the new work.

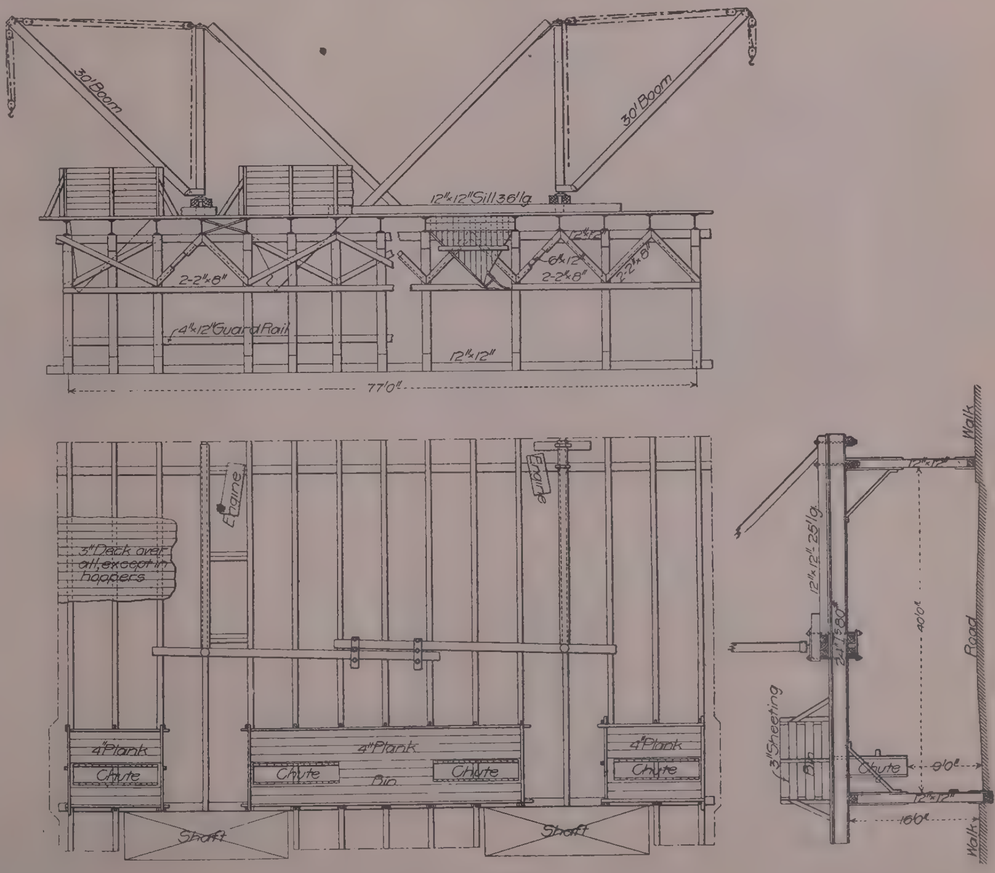
The foundations of adjacent buildings are examined, and as in most cases where their footings are on the sand close to and considerably above the subway walls, it is necessary to carry them down below the limits of the excavation. The superstructures are generally supported in the ordinary manner on steel or wooden needlebeams while the old foundations are removed. A trench is sheeted down to subgrade under them and is filled with concrete forming a continuous footing from 10 to 20 ft. high and from 3 to 6 ft. wide on which concrete piers or walls are built and connected with the old masonry. The sheeting in the lower part of the trench is permanent and serves as a form in which the concrete is cast after the transverse braces are removed. The upper part of the concrete is usually cast in forms which are entirely removed after it has set.



Supporting Deck with Posts in Sheeted Pits.



Deck Supported on Vertical Shores in Short Sections.



Elevated Hoisting and Storage Platform.

In some cases where the buildings are very heavy, the soil treacherous or the ground-water level too far above sub-grade the trench was sheeted down only as far as water line and the old foundations were underpinned without further excavation by the use of wooden or steel needle-beams temporarily carrying the superstructure, while trenches were excavated and new and deeper foundations constructed, or by other methods suited to the special conditions encountered.

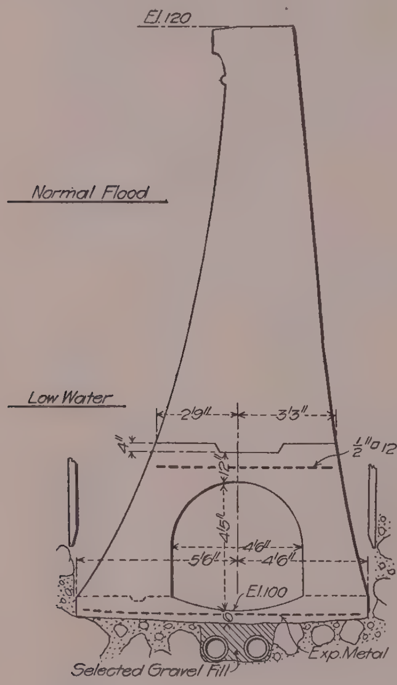
In one of the two principle methods adopted, the underpinning is followed by the completion of the excavation in two or three full-width cuts carried down to sub-grade substantially like the first one with benches from 20 to 50 ft. long. The sides are retained by two or three corresponding tiers of sheeting and the bracing and shoring is continued as previously with a very simple arrangement of vertical, longitudinal and transverse timbers continuous from side to side of the excavation forming caps at every story of the verticals.

When the second cut is made before the underpinning is done, it is not excavated the full width of the final trench but has a berm from 6 to 10 ft. wide cut on each side large enough to contain a slope at an angle of repose of the material and thus provides for the safe distribution of pressure from the buildings and avoids any danger of undermining their footings, or the displacement of the soil. Most of the excavation is above water level so that little pumping has been necessary and as the material is generally soft and loose it is easily excavated by shovels and removed in 1-yd. steel buckets on flat cars pushed by hand to the face of the bench or to the foot of the shaft on 24-in. Koppel industrial tracks laid and shifted and extended as required by the progress of the work.

By the second method of excavation the use of short sections of vertical posts is eliminated and the street platform together with the trolley tracks, pipes, mains and conduits are carried on long vertical posts which extend to sub-grade. When the first cut is made the upper transverse timbers about 12 ft. apart are supported practically at the surface on both sides of the excavation and the two intermediate ones by vertical posts about 14 ft. apart, between the side walls and the center columns of the two-track subway. The intermediate posts are at first seated on 12 x 12-in. longitudinal stringers about 30 ft. long. Transverse pits about 5 ft. wide and 22 ft. long at the top, are sheeted down to sub-grade in the planes of the transverse bents and receive pairs of 10 x 10-in. vertical posts 14 ft. apart. The transverse sills supporting the intermediate vertical posts in the upper cut are jacked up enough to release the short vertical posts by which they were formerly supported when they are lowered to bearing on the long vertical posts beyond which they cantilever a short distance at each end. Subsequently no more regular timbering is necessary except horizontal transverse struts to brace the sheet pile rangers across the trench. By this method the progress of the excavation is more rapid and uninterrupted, but as it is thought that the gain is fully balanced for the labor and large costs of sheeting the transverse pits, it has not been so much used as the first method described.

Provision is made for the continuous removal of the soil and the delivery of materials from the excavation without any street obstruction by means of the elevated platforms installed at each pair of shafts. These platforms vary somewhat in detail, but are all of them simple bridges covering the street from curb to curb with sufficient clearance for trolley cars and all other traffic below them and provided with derricks and hoisting engines for handling materials and bins for storing spoil and delivering it rapidly to wagons in the street. They occupy no street space except a strip 12 in. wide and from 50 to 80 ft. long on each curb and provide elevated yards available to the contractors for many purposes. The details vary somewhat in the different platforms, but the general features correspond to those of the platform designed for the shaft on Canal St. near Elizabeth St. Transverse bents 40 ft. long in the clear and 11 ft. apart on centers support a platform 50 ft. wide and 80 ft. long, which has a general clearance of 15 ft. above the pavement and carries two stiff-leg derricks with 10-ton, 30-ft. booms commanding both shafts and the entire area of the platform.

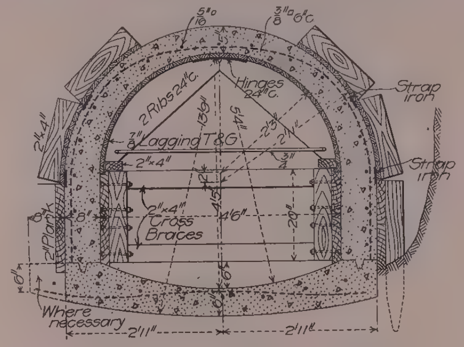
Each of the transverse bents is made with a 24-in. 80-lb. I-beam seated on a continuous 12 x 12-in. longitudinal girder and knee-braced with pairs of 4 x 3-in. bent angles to the 12 x 12-in. vertical posts which are scabbed to the upper and lower longitudinal timbers. Each row of vertical posts is braced longitudinally with a 4 x 12-in. guard rail, with a line of double 2 x 8-in. planks bolted to opposite sides about half-way between the floor platform and the pavement. The upper panels have zig-zag 12 x 6-in. braces with bearing on angle blocks at the upper ends and are dapped into the sides of the posts at the feet and together with the pairs of 2 x 8-in. braces form triangular trusses supporting intermediate 24-in. I-beams at the center points of the upper longitudinal piers. In some places these 6 x 12-in. braces are omitted and the intermediate I-beam is supported by a vertical post instead.



Section B with Retaining Wall.

The derricks are of ordinary construction with 12 x 12-in. transverse and longitudinal sills anchored with 1-in. bolts and 12 x 1-in. bearing plates to the transverse girders. The storage bins have an aggregate capacity of about 100 cu. yd., are built on the platform and are provided with chutes commanded by swinging gates, through which their contents are discharged to wagons in the street below. The large bin has a capacity of 72 cu. yd., and the small ones each have a capacity of about 25 cu. yd. The platform is proportioned to carry the derricks, two Lidgerwood hoisting engines, the bins filled with earth and an additional load of 150 lb. per square foot.

Excavation on this section was commenced in July, 1907, and it is now about 60 per cent. completed; about an equal portion of the underpinning has been finished and it is expected that the erection of some of the steel roof girders will soon be commenced. An average force of about 250 men is now employed in two 8-hr. shifts and the headings are advanced about 15 ft. a day.



Dimensions and Forms, Section A.

Mr. H. B. Seaman is chief engineer of the Public Service Commission, now in charge of this work; Mr. George S. Rice, engineer of subway construction, and Mr. George Hallet Clark, division engineer. The contractor is the Degnon Co., Mr. H. C. Sanford, chief engineer, and Mr. Francis D. Fisher, engineer in charge.

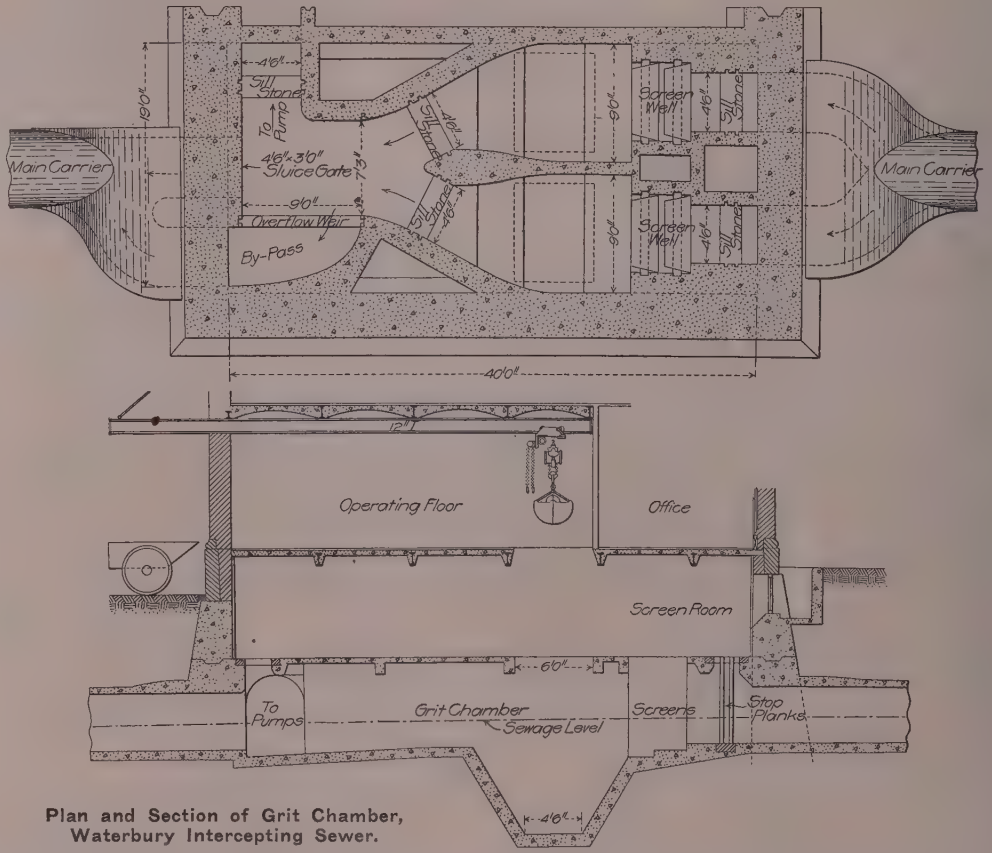
Casting Threaded Holes is a growing practice among certain machine and manufacturing concerns, being accomplished by inserting in the molds threaded wrought-iron nuts properly located and secured by means of projections from the cores. They may in this way be very exactly placed and obviate the necessity of drilling and tapping operations, while the wrought-iron threads have greater strength than threads tapped into the cast-iron.

The New Main Intercepting Sewer at Waterbury, Conn.

By Wm. Gavin Taylor, M. Am. Soc. C. E.

Leading to the development of sewage purification works at Waterbury, Conn., the construction of a main valley intercepting sewer has been a necessity. The sewerage system of the city is divided into relatively small districts, each of which has discharged into the Naugatuck River. Along the valley, running close to the stream, has been located a reinforced concrete intercepting sewer, of horseshoe shape, 4 ft. 6 in. x 4 ft. 5 in., locally termed the main carrier, having a length of over three miles. Of this length a mile and a half has been completed and is in use, a half mile is under contract and a mile is to be built.

The main valley through which the main carrier must pass is young, geologically, and consequently the gradient of the river is relatively great and the hillsides steep. This, together with the fact that the underlying rocks are entirely ancient crystallines, supporting but a shallow covering of glacial drift, has limited the location of the intercepting sewer to a narrow tract lying along the bank or in the bed of the river.



Plan and Section of Grit Chamber, Waterbury Intercepting Sewer.

The work now finished or under contract has been divided into three sections, and the work in these sections has been carried on by the following contractors: Section 1, McGovern Construction Co., Trenton, N. J., and continued by the Crouse Construction Co., Perth Amboy, N. J.; Section 2, Fred T. Ley & Co., Springfield, Mass., and Section 3, Long & Little, Leominster, Mass.

Trench excavations have been principally through water-bearing gravel, ranging from coarse to fine. Much trench work has varied in depth from 20 to 26 ft. At two points the sewer location passes through drumlins, and through these masses of glacial drift the sewer was constructed in tunnel, the length of both tunnels being 795 ft.

The contractors installed two Lambert cableways, having a clear span of 350 ft. These machines were operated for trench excavation at the head of the opening, for refilling at the rear and for the placing of concrete for the sewer structure. Concrete was principally mixed by a machine placed near the head-tower of the cableway, in small batches, discharged into a cyclopean bottom-dump bucket and conveyed to the work. The buckets were very tight and held the soft concrete mixture without loss.

Ground water was encountered throughout the entire length of the sewer now in use. On the river portion of the work water was so abundant that the trench was excavated in short sections and the water controlled by the combined use of a 10 and an 8-in. centrifugal pump.

The rock encountered in the trench excavations has been granite-gneiss of irregular fracture. A total of 15,000 cu. yd. has been removed from trenches averaging 8 ft. in width, at a cost, for labor, tools and materials, of $2 per cubic yard, with common labor at 17½ cents per hour. A typical rock trench is shown in one of the illustrations.

Several sewer sections have been used, varying with conditions of depth, character of soil and particular use. Normally section A, shown in the drawings, was constructed, although variations in the width of the footing course were frequent. Often the invert course was extended to a width of 8 in. outside the vertical side walls. For 1,500 ft. the sewer location ran through the bed of the river, where conditions favored the construction of a river wall for the reclamation of certain low-level lands lying adjacent to the right bank of the stream. Section B was designed to serve both as a retaining wall foundation and as a sewer structure, and, again, further upstream, where the sewer location skirts the river edge of a projected park, the section is variable.

A complete separation of the surface waters from the main carrier cannot be effected for some years and consequently during this interval a considerable amount of road detritus and other grit will be carried with the sewage stream to the pumping station. To effect an economical removal of this mineral matter a grit chamber, shown herewith, has been designed and is now under contract. At the entrance of the station a bell-mouth divides the flow. After the passage of the sewage through a double basket screen, presenting two staggered rows of vertical rods for the interception of coarse matter, it passes into a chamber where through an enlargement of the channel, both horizontally and vertically, the velocity of the sewage stream is reduced from 4.5 ft. per second to about 1 ft. per second. The reduction in velocity is sufficient to cause the precipitation of the coarser mineral matters and their accumulation in the sump chamber. From this chamber it is planned to remove the grit, at intervals of two or three days, by means of a mechanical equipment especially arranged for this particular service.

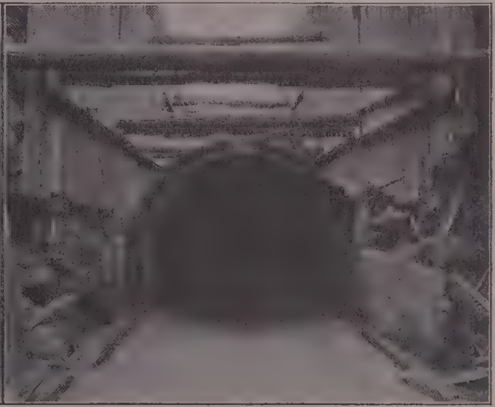
Forms for the main carrier section have been principally of wood and constructed by the several contractors in a similar manner to that shown in the accompanying drawing. The invert section has been built as a first operation, the invert screeded and troweled into perfect form and allowed to set 36 to 48 hr. before the concreting of the arch section above. The vertical sides of the inner forms are readily removable and the semi-circular arch above is hinged at the soffit and is collapsible. Lagging is of spruce, ⅞ in. thick, with tongued and grooved radial joints, and toe-nailed to the 2-in. plank ribs. The lagging strips are driven to a close fit and the exterior curve planed and scraped to a true surface.

The first cost of these forms has averaged $18.00 per 10-ft. length and the cost of forms per foot of sewer built, including first cost and maintenance in excellent condition, has averaged 10 cents.

Cableway on Trench Excavation.

Finished Invert, Retaining Wall Section.

Steel Reinforcement Cage for Sewer.



View of Finished Portion, Section A.

Concrete has been uniformly mixed to a mushy consistency and poured into practically watertight forms. Proportions used in section A were 1 part Atlas Portland cement to 7½ parts of aggregate, graded to as near the curve for ideal density as practicable under the local conditions. Concrete for section B consisted of 1 part Atlas cement to 9 parts of graded aggregate.

The contractors have used great care in the churning of deposited concrete, with the result that both the interior and exterior surfaces of the structures have been very smooth. Plastering of the surfaces has been avoided. Void spaces caused by small masses of entrained air, or otherwise, have been brushed with grout or pointed, and the surface struck with a wooden float and then rubbed until down to the near line of the sewer.

Petrolene, a crude petroleum jelly, has been used with success upon the wooden forms for the prevention of the adherence of concrete. Soft soap and both light and dark mineral oils have been used for a like purpose but with less satisfaction.

Both expanded metal and square twisted steel rods have been used as reinforcement in parts of the work. The location and general spacing of the steel during the use of square rods is shown in the drawing of section A. Rod reinforcements were bent and made up on the bank into the form of cages and these were lowered into the excavations and set in their proper positions over the forms.

Observations upon the sewage flow in the main carrier, at depths up to the springing line, have shown that the value of *n* in Kutters formula, when applied to the sewer flow, is not greater than 0.010. Opportunities for observations upon greater depths have not yet been presented.

Of the mile and a half of main carrier, now in use, all has been through water bearing soil and much of the sewer is from 4 to 12 ft. below the ground water table. The interior surface presented in this length to percolation is 118,000 sq. ft. and from this area the total seepage has been less than 0.03 cu. ft. per second.

Cost records kept under the several contracts and assembled into a composite form, Table 1, show what is considered to be the normal cost of section A under the local conditions. Common labor has averaged 17½ cents, sub-foremen 30 cents and general foremen 50 cents per hour.

TABLE I.

NORMAL COST PER LINEAR FOOT OF 53 x 54 IN. REINFORCED CONCRETE SEWER—STANDARD SECTION "A."

Steel reinforcement, 17⅛ lb.	$ .43
Making and placing reinforcement cages	.14
Wooden interior forms, cost, maintenance and depreciation	.12
Wooden exterior forms, cost, maintenance and depreciation	.05
Operation of forms	.16
Coating oil	.01
Mixing concrete	.30
Placing concrete	.27
Screeding and finishing invert	.08
Storage, handling and cartage of cement	.08
0.482 bbl. cement at $1.53	.74
0.17 cu. yd. sand at $0.50	.09
0.435 cu. yd. broken stone at $1.10	.47
Finishing interior surface	.01
Sprinkling and wetting completed work	.02
Total cost per linear foot	$2.97

Equivalent to $8.02 per cubic yard.

The sewage work described is being executed under the direction of the Board of Public Works with Mr. R. A. Cairns, M. Am. Soc. C. E., as city engineer and with the writer in charge of the design and construction work.

PANAMA HEALTH CONDITIONS during 1907 were better than ever before, according to the report of Col. Gorgas. The death rate among the white employes of the Isthmian Canal Commission, who averaged 10,709, was 16.71 per thousand, while among the negro employes, averaging 28,634, it was 33.28 per thousand. The rate from disease alone among the white American employes was 6.74. During the year the average number of employes was 39,343, of whom an average of 987 were sick each day, a rate of 25 per thousand. The malarial cases were only half as prevalent as in 1906.

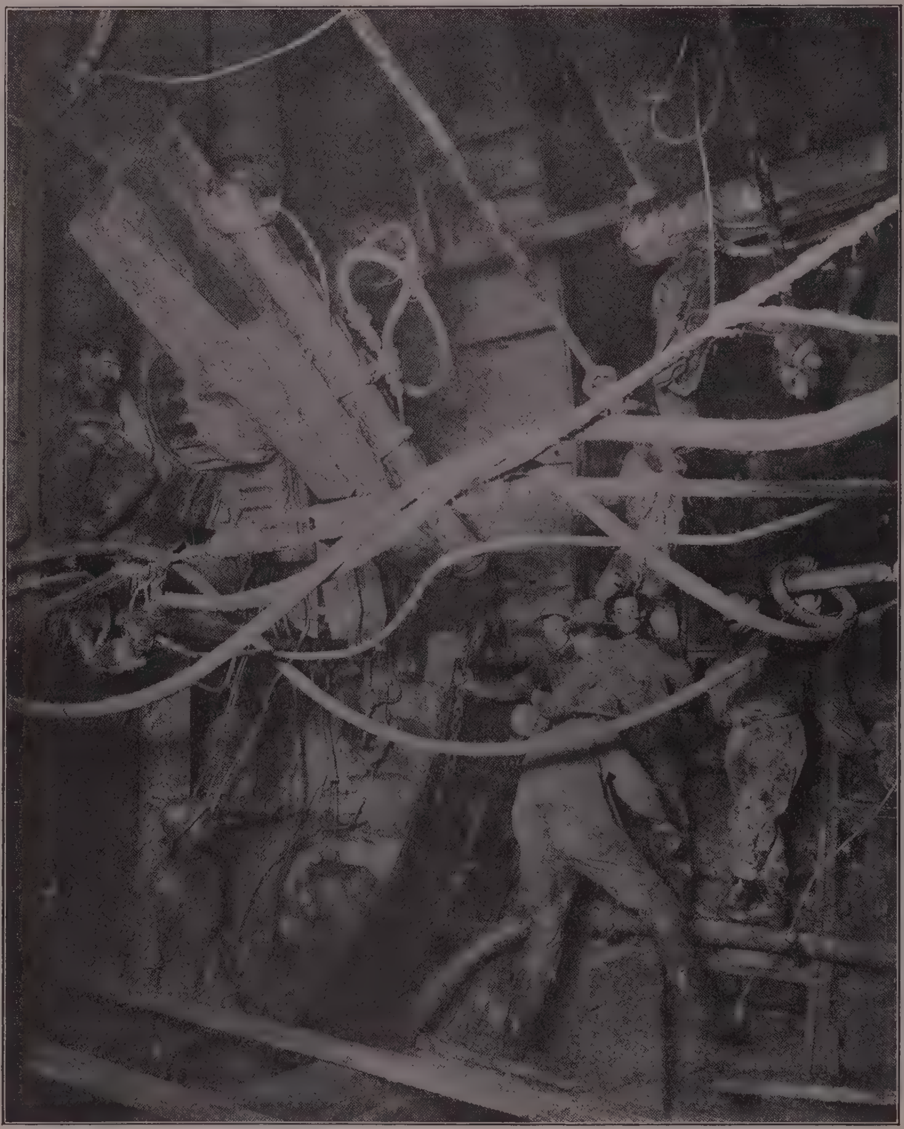
THE MEETING OF THE FOUR EAST RIVER TUNNELS OF THE PENNSYLVANIA RAILROAD.

The meeting within the last month of the shields of all four tunnels of the Pennsylvania R. R. under the East River between New York City and Long Island City, marks the successful completion of the most difficult of subaqueous tunnelling projects. Four independent tunnels of very large section, each 23 ft. in diameter and about 3,900 ft. long, have been driven simultaneously from eight headings by the shield method, under compressed air at pressures varying from 30 to 36 lb. per square inch, and approximately 16,000 ft. of cast-iron lining have been placed, the greater part of the tunneling being through quicksand, demanding careful handling, eternal vigilance and not a little danger to the men engaged in the work. At the present time the cutting edges of the eight shields, two in each tunnel, are in contact under the bed of the East River, and their variation from true grade and line is but a few hundredths of a foot. The shields are now being cut out preliminary to placing the few remaining rings which will complete the cast-iron linings from shore to shore.

Connected with this work, by reason of being embraced in the same contract as the subaqueous tunnels under the East River and being driven by the same method, are the four land tunnels in Long Island City, extending eastward, from the river shafts at the bulkhead lines, about 2,000 ft. to the portal at Thompson Ave., where the tracks rise to the surface and run into the Sunnyside Yard. The entire contract thus embraces about 24,000 ft. of single-track tunnel, all driven under compressed air, and necessitating the employment of an unprecedented number of men working under pressure.

The East River work and the land tunnels in Long Island City are part of the great system of improvements of the Pennsylvania R. R. extending from Harrison, N. J., to Long Island; the line across the Hackensack Meadows, the rock tunnels of Bergen Hill, two single-track tunnels under the Hudson River, the immense new terminal in Manhattan Island, bounded by 7th and 9th Aves. on the east and west and by 31st and 33d Sts. on the south and the north respectively and the two land tunnels from the terminal site to the shore line of the East River, where connection is made with the work above referred to. In addition to the elaborate system of tunnels and the immense terminal, considerable surface work is required, notably in the construction of the Sunnyside Yard, in Long Island City, for handling and storing passenger coaches and making up trains for the West, and the construction of the New York Connecting R. R., which, by means of a bridge across Hell Gate, will give a physical junction of the Pennsylvania R. R. and the New York, New Haven & Hartford R. R. At the present time the tunnels, both land and subaqueous, except those through Bergen Hill, have been driven through and are being completed, the excavation is almost finished at the terminal site and the erection of the steel for the terminal building has been commenced, the embankments across the Hackensack Meadows and the necessary piers and abutments are well along toward their final condition and mountains of spoil are being moved at Sunnyside and used for extending the yard area.

The East River tunnels extend from two shafts at First Ave., New York City, to two similar shafts at the bulkhead line in Long Island City near the terminals of the Long Island R. R. Two of the lines in Manhattan are under 32d St., and the other two under 33d St., converging toward the Long Island shore, the distance between the shafts on the west side of the river being 225 ft., and between those on the east shore 103 ft. The two tubes starting from the same shaft are parallel and on 37-ft. centers. Each tunnel measures 23 ft. in external diameter and is composed of cast-iron rings 30 in. long, each ring being divided into eleven 2,000-lb. segments, about 6½ ft. long, and a key segment, 30 in. long, located near the crown. All segments have a web 1½ in. in minimum thickness and flanges 11 in. wide over all and about 2½ in. thick, those on the long sides being braced by transverse webs. The outer faces of all flanges are planed and the joints are recessed 1½ in. for calking. The rings are bolted to each other, as are the segments of a ring to the adjoining segments, by 1½-in. bolts. A grout pipe is provided in the web of each segment, being normally closed by means of a screw plug, so that all cavities outside of the iron lining in the rock section can be pumped full of grout, and, where the tunnel is in soft material, a sufficient protecting coating forced to the outside.

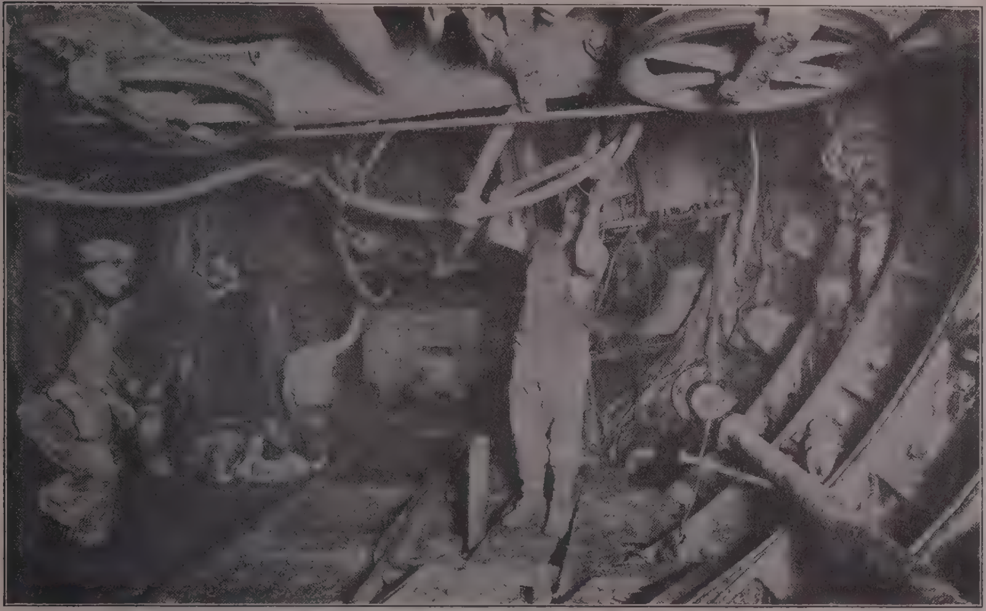


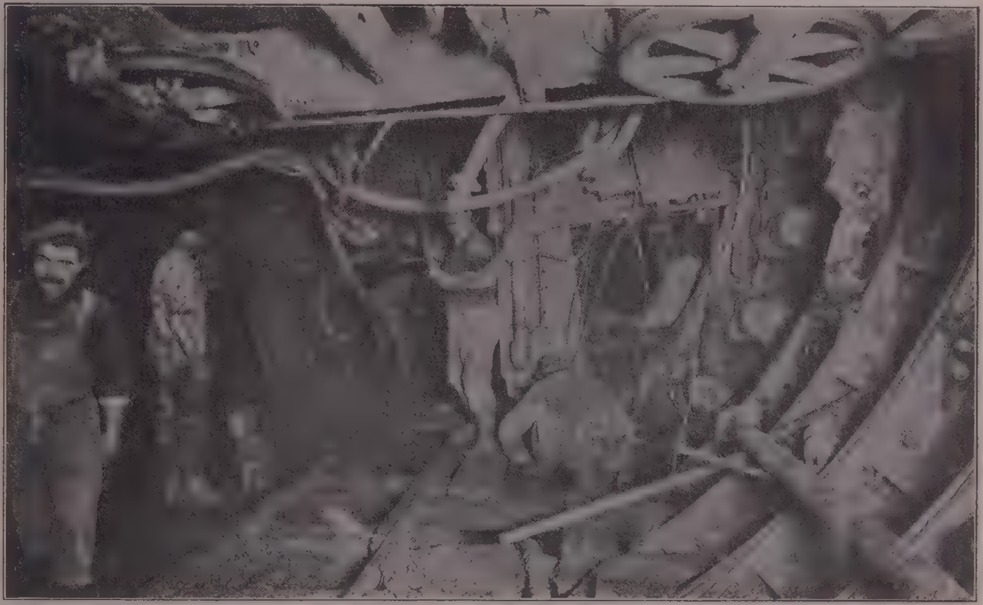
Segment of Ring Just Put into Place by Hydraulic Erector.

The interior of the tunnels will be lined with concrete, having a minimum thickness of 2 ft. above the springing line and reducing the clear radius there to 9½ ft. Below the springing line bench walls are carried up on each side to contain the ducts for power, lighting, telephone and signal wires. These bench walls will also serve as a walk for the workmen engaged in the tunnels and for passengers, in case it should be necessary to allow them to leave the tunnel should the trains be stalled. At the deepest portion the base of rail is about 90 ft. below the high water line, and in one place the top of the tunnel comes within 8 ft. of the normal bed of the river. The complete design of the tunnels was described in The Engineering Record in the issues of Oct. 10 and 17, 1903, and a general description of the project in the issue of July 7, 1906.

The work was started by sinking shaft linings, made of two shells, filled in between with concrete and arranged so as to be used as caissons, if necessary. These shafts were 40 ft. wide and 74 ft. long, the steel and concrete lining extending in the Manhattan shafts down to depths of 40 and 50 ft. respectively for the south and north caissons, and 84 ft. for both of the caissons in Long Island City. On the Manhattan side they were sunk without air pressure, and on reaching the rock the excavation continued in the open, the walls being faced with a concrete lining. On the Long Island side, however, they were sunk under pressure, one of the shafts being located in a slip having a depth of 16 ft. The caisson for the latter was built on a falsework of piles, and lowered to the bottom with jacks. When the proper depth had been reached the bottom rock was waterproofed and concreted and the roof of the working chamber removed. Inside of these shafts the tunnel shields were erected and when completed were pushed out of the shaft through the circular drums in the river side. These circular drums were temporarily closed by movable bulkheads until it was ready to start the shields. The design of these caissons, and the method of their erection and sinking were fully described in The Engineering Record of July 14, 1906.

All of the eight shields used for the subaqueous work and the two shields used for the land tunnels in Long Island City were duplicates in design, save for the fact that those for the land tunnels were built somewhat lighter than those for the river work. In outside dimensions they measured 23 ft. 6½ in., were 18 ft. 6 in. long and weighed about 542,000 lb. each. They were divided across the section by two horizontal platforms, one 8 ft. and the other 15 ft. above the lower edge of the shield, and by two vertical diaphragms parallel with the axis of the tunnel, cutting the shield into nine separate compartments, as shown in one of the accompanying illustrations. Transverse, i. e. perpendicular to the axis of the tunnel, there were two vertical bulkheads, 2½ ft. apart, made with heavy angle-iron frames and ½-in. steel plates. In front of the forward bulkhead these nine compartments or chambers could be closed with vertical transverse adjustable shutters, movable back and forth by powerful screws that enabled them to be pushed up against the face of the earth in front of the shield, and likewise to be withdrawn from the face so as to clear it when the shield was advanced. The miners worked in front of the forward bulkhead with or without the protection of the shutters, two of them being stationed in each of the three large chambers and one in each of the six small chambers. When the shutters were in service, small apertures could be opened or closed by sliding doors, leaving holes of small area through which, under the worst conditions, the soft mud and sand were excavated. The spoil was shoveled up and deposited in inclined chutes passing through both diaphragms and delivering to the rear of the shield, where it was shoveled into dump cars and drawn by cable traction to the air locks. When the ground was not bad the miners attacked the whole face of the heading corresponding with each compartment of the shield.


Rear End of Shield, Showing Spoil Car in Center Compartment.


View of Hydraulic Jacks, Rings in Place and Under Side of Grouting Platform.

Provision was made on the upper half of the shield for a movable semi-circular hood, 6 ft. long, forming an extension of the shield so as to afford protection from soft upper stratum when it was necessary to excavate rock below it. The material encountered in the work included mud, quicksand, solid rock, rock and sand, rock and boulders and sand and boulders, offering a very great variety of problems in the method of handling the work. The difference in the water pressure at the crown and at the bottom of the shield naturally introduced quite a problem in balancing the air pressure against the column of water, particularly in the soft material which was encountered through so much of the length. When the pressure was just sufficiently high to keep the upper half of the face dry, the lower half would be very fluid, making it extremely difficult to prevent the shield from sinking. Despite this difficulty the grade was maintained with remarkable precision, as was shown by the excellent checks when the four tunnels were joined up.

Another difficulty connected with the proper regulation of the air pressures within the tunnel arose from the small depth of the cover between the top of the tunnel and the river bed, increasing the possibility of blow-outs if the pressure was raised so as to drive out the water and dry the bottom of the face. To lessen this danger, permission was obtained by the Pennsylvania Railroad from the War Department to place a cover of clay on those parts of the river bed where the tunnel came close to the bottom of the water. The company secured under-water rights at Haverstraw, N. Y., on the Hudson River, where the clay was dredged and placed in scows. Quantities of this clay were at hand at all times and when required the scows were located at the required points by intersecting transit lines and the blanket deposited. A total of about 500,000 cu. yd. of clay were deposited in the river, and now that it has served its purpose, it is being redredged and sent out to sea. With the assistance of this blanket excellent progress was made, the pressure of the air being kept about equal to that of the water column above the axis of the tubes.

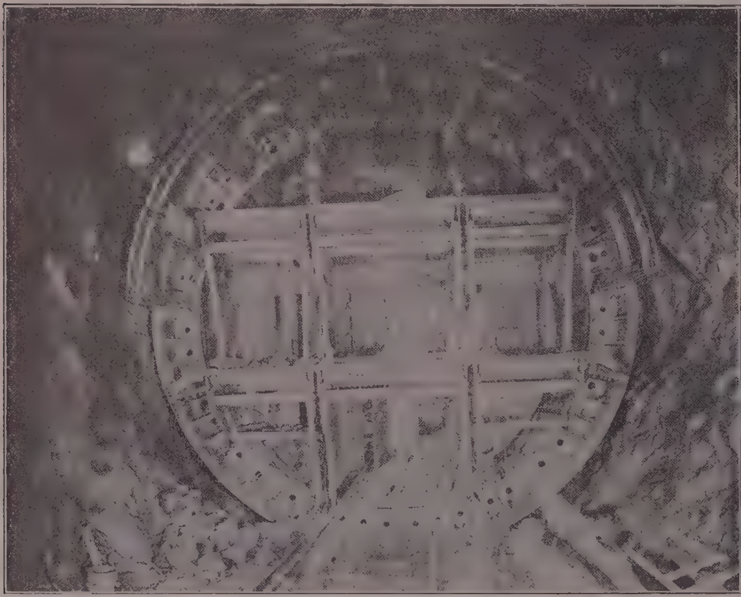
The cast-iron lining was put in place by two independent hydraulically-operated erectors attached to the rear bulkhead of the shield and entirely within the tail-piece. These erectors, which are shown in different positions in accompanying photographs, had two hydraulic cylinders, one of which was used for raising and lowering the segments of the ring and the other for turning them through any angle and placing them at the proper points of the circumference. The latter movement was accomplished by a toothed rack which operated a pinion on the arm supporting the other cylinder. This double motion allowed the erector to take a segment from the car on which it was brought into the tunnel, revolve it to the proper angle and then extend it radially and hold it in position until bolted to the adjoining segments.

The power for advancing the shields was obtained through 27 hydraulic jacks, each 9 in. in diameter, operated with a water pressure of 6,000 lb. per square inch, thus affording a total shoving pressure of 5,000 tons. Each shove of the shield amounted to 30 in., the length of one ring. A full description of the shield and its various attachments was given in The Engineering Record of July 28, 1906.

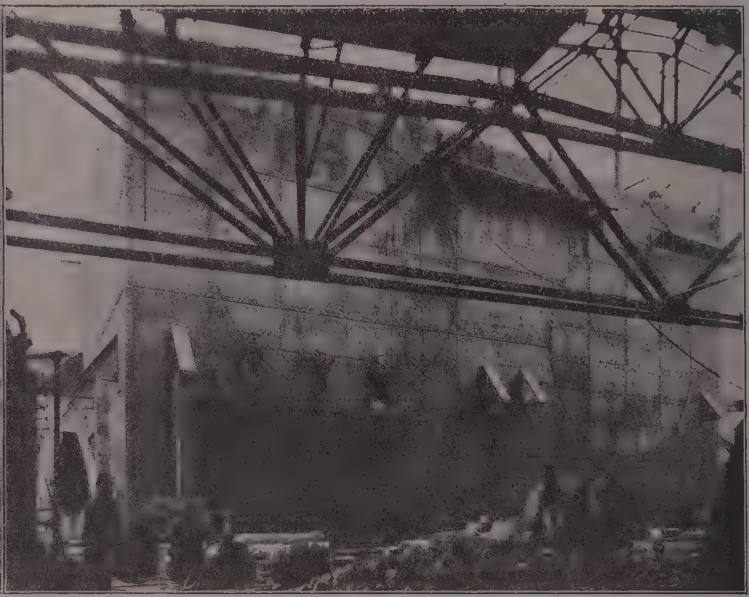
Immediately following the shield and pulled along by it was a platform upon which was mounted the apparatus for mixing and ejecting the grout to the outside of the cast-iron lining. It consisted of a motor-driven grout mixer and a suitable pump. This platform was also used by the men who calked the joints between the various rings and the segments. A cable haulage system was used for operating cars over a double-track which was kept close up to the shield, for the delivery of the iron segments, cement and other materials. In order to avoid constant change in the length of the cable, as the shield was pushed forward, a system of counterweights was adopted which took care of a considerable amount of slack and made a change in the length of the cable necessary only at considerable intervals.

Extending back from the shield throughout the entire length of the tunnel was an elevated gangway carried above the springing line and providing a safety and emergency exit in case the tunnel should be flooded while driving operations were in progress. Forming an essential part of this safety exit scheme were steel diaphragms, or safety screens, as they are called, which were built transversely across the upper half of the tunnel at convenient intervals. In case the tunnel was flooded the air between these screens would be trapped, on the principle of a diving bell, and security offered to those upon the elevated passageway, which was well above the bottom of the screens. When the work was started there was naturally but one bulkhead between the outside air and the shields, but as the tunnel progressed a second bulkhead was put in and fitted with air locks, thus allowing the full air pressure to be attained through the medium of two locks instead of one.

In the lock located at the shaft about half of the pressure, approximately 15 lb., was put on and the increase to the total pressure, varying from 30 to 36 lb., was maintained only between the second bulkhead and the face where excavation was in progress. These bulkheads are of massive concrete, 10 ft. thick, and contain three air locks, two side by side at the bottom, with their floors at the level of the spoil tracks, and the third in the upper half of the circular section. The two lower locks are used for handling materials, while the upper one, called the emergency lock, is reserved for the use of the men and has its floor at the level of the suspended gangway above referred to. Except during the period when men are going through the lock, the door opening to the inside of the tunnel is always kept open so as to cause no delay should any accident require the immediate use of the lock for exit from the tunnel.



Front View of One of the 23-Foot 6 1-2-Inch Shields.



Shaft Caisson, Showing Drums Closing Tunnel Entrances.

On account of the great number of men constantly required to work in compressed air in the various headings, exceptional precautions have been taken to insure their safety and to give them proper attention in case of attacks of the "bends" or caisson disease. A medical staff is in constant attendance at both shafts and six hospital locks are provided. These hospital locks have two compartments, so that when a patient is under treatment in the inner lock, attendants and physicians can enter and leave without changing the pressure to which the patient is subjected. Each applicant for work under pressure receives a thorough physical examination and a complete record is made as to his condition and such other facts as are desirable for permanent record. The applicant is then subjected to a preliminary pressure in the air and if this test and the physical examination prove satisfactory, he is accepted.

The efficient handling of a work of this character necessarily requires an extensive surface plant for the hoisting and disposal of excavated material, storage of cement, cast-iron segments, tools and various supplies, locker rooms and facilities for the comfort of the employees, and power houses for the compressors and electric generating equipment. Two large plants have been erected by the contractors, S. Pearson & Son, Inc., one at the Manhattan and one at the Long Island City shafts. The power house on the Manhattan side contains seven 16 and 34 x 42-in. Corliss duplex compound air compressors of Ingersoll-Sergeant make for supplying air to the tunnel, two high-pressure air compressors of the same make for supplying the air drills, and high-pressure hydraulic pumps for supplying power to operate the hydraulic jacks on the shields. The rated capacity of low-pressure air is 35,000 cu. ft. of free air per minute. The equipment on the Long Island side is quite similar to that on the Manhattan side. A complete description of the contractor's surface plants was given in The Engineering Record of July 21, 1906.

The design and construction of the East River tunnels has been in charge of Mr. Alfred Noble, as chief engineer for the Pennsylvania Railroad, Mr. Samuel Rea, vice-president of Pennsylvania Railroad, being in general charge of all the New York improvements. Mr. C. L. Harrison is principal assistant engineer, Mr. J. H. Brace and Mr. Francis Mason resident engineers on the Manhattan side, and Mr. S. H. Woodard resident engineer on the Long Island side.

The contractors are S. Pearson & Son, Inc., of which company Sir Weetman D. Pearson is president. Mr. E. W. Moir, vice-president of the Pearson company, has general supervision of the work; Mr. Henry Japp, is director and managing engineer, and Mr. A. W. Manton, deputy managing engineer.

A New Plate-Girder Swing-Bridge, weighing in its launching condition about 500 tons, was recently put into place for the Victoria Railway over the River Hull, at Sculcoates, England, after having been completely erected on shore. The bridge has a length of 160 ft. over all, carries two tracks, and has two main girders, with a clear distance between them of 27 ft. 6 in. A temporary foundation was built on the east bank of the river for supporting the bridge during erection. The bridge, when completed, including its machinery and an overhead controller house spanning the tracks, was moved into position on a trestle, consisting of a double row of piles, carrying a double line of rails under each main girder. Four six-wheeled bogies were placed under each girder. The structure was moved into place by a locomotive attached to the end of a 12-part tackle.

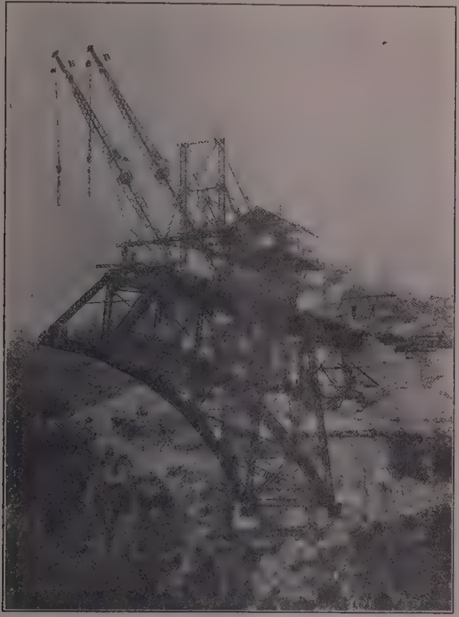
Cantilever Bridge Erection on the Guatemala Northern Railway.

The 60-mile section of the extension of the Guatemala Northern Ry. from El Rancho to Guatemala City is through a high mountainous country in which there are 57 single-track bridges with a total weight of about 6,000,000 lb. The principal structures are the Rio Fiscal bridge, with maximum spans up to 180 ft. and ten viaducts chiefly consisting of 30 and 60-ft. plate-girder spans excepting for the highest parts of the structures, where there are riveted truss spans up to 120 ft. The viaducts were designed to be erected by an overhead steel traveler with a sufficient reach to build one tower in advance and set the plate-girder spans on it. The same traveler was used for the erection of the viaduct truss spans which, however, were built out as cantilevers, and the same traveler was used for the successive cantilever erections of the two semi-spans of the arch trusses.

The main span of the Rio Fiscal bridge has two spandrel braced three-hinged riveted arch trusses with horizontal top chords, 209 ft. long and 12 ft. apart on centers. The trusses are 15 ft. deep at the crown and 53½ ft. deep at the skewbacks and are battered 1:8. The cantilever erection reactions of 175,000 lb. for each truss were provided for by anchorages of eye-bars in inclined lines reaching from the ends of the top chords to the bases of the heavy masonry abutment piers. Each of these four anchorages contained a toggle joint operated by a gear-driven screw fitted with a capstan head for hand levers which, together with the principal details of construction, were illustrated in The Engineering Record of March 23, 1907.

The traveler has two riveted trusses 10 ft. deep and 10 ft. apart on centers and about 55 ft. long over all, which are mounted on four double-flange wheels and are connected by top-chord transverse beams and X-bracing. The vertical posts at the forward end extend about 23 ft. above the top chords, forming masts for a pair of 60-ft. steel booms seated on the ends of the lower chords. The upper parts of the masts are connected by transverse horizontal struts and two panels of X-bracing and are knee-braced on the outside to a horizontal transverse strut projecting beyond the top chords of the trusses. The upper ends of the masts are back-stayed by a pair of inclined tension angles running to the rear ends of the lower chords of the trusses. A platform for the hoisting engine was built on the rear ends of the top chords, leaving clearance beneath it for material cars to deliver the steel members to the traveler derrick booms. The traveler was described in The Engineering Record of Feb. 2, 1907, and has been very successfully used for the erection of the Rio Fiscal bridge and the Las Vacas viaduct, 743 ft. long and 229 ft. high, with 30, 40 and 75-ft. spans, as described in The Engineering Record of Jan. 26, 1907.

The bridges were designed by Mr. V. G. Bogue, New York, Mr. W. H. Kennedy and Mr. A. W. Buel, associate engineers on railways and bridges, respectively; Mr. S. F. Shaw is chief engineer of the railway company, and Mr. J. H. Pope, bridge engineer. The erection method was designed by Mr. Buel. The Baltimore Bridge Co. was the contractor for the fabrication of the steelwork and Mr. W. T. Penny is the contractor for the erection.



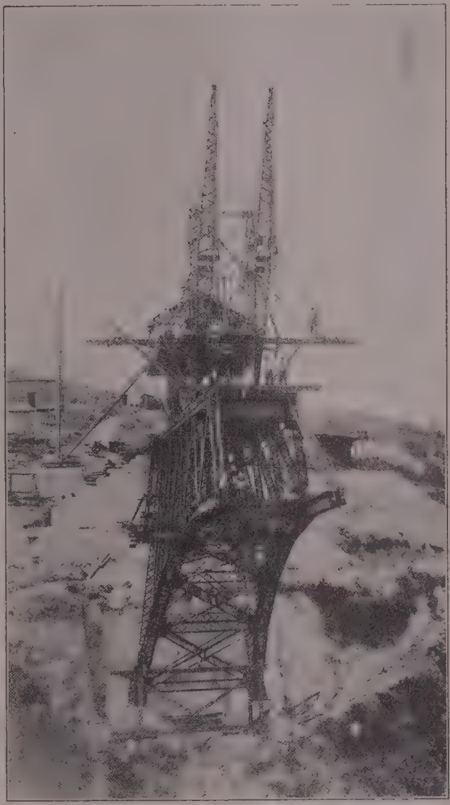
Traveler on First Half of Arch.

In a recent report to Mr. Bogue Mr. Penny writes as follows:

"The actual erection of the arch took 18 working days with a force of six American bridgemen and 25 natives of Guatemala and Mexico. I have now in my employ about 30 of these men, whom I selected from time to time. They have become quite efficient bridgemen, quite as good as some of the ordinary bridgemen in the United States and much better than several of a gang of ten bridgemen who were shipped to me from Havre de Grace some time ago. These bridgemen came contracted for 55 cents per hour, and this rate would pay five of these natives without including the bridgemen's transportation. I use only natives for heating rivets. Between the two compressors I keep about seven gangs of riveters going. These men heat from 250 to 300 rivets per day of 10 hours, which is the average day's work per hammer. I use them entirely on my nigger-heads with good results, as may be inferred from the fact that not once during this work has a piece of iron been dropped, and telegraphing iron is not the easiest class of nigger-head work. Las Vacas viaduct, 230 ft. high, was painted by these men, and for the second coat of paint I used absolutely no scaffold whatever and the only lines used were hand-lines for lowering paint. With a foreman who talks Spanish and knows how to handle these people a saving of 25 per cent. on erection can easily be made without including that saved on transportation of bridgemen from and to the United States.

"The Rio Fiscal arch was erected without a hitch of any sort. The toggles acted admirably and are *certainly the greatest hand power I ever saw developed.* I raised one side of the arch 6 in. with the heavy traveler used on the erection of Las Vacas viaduct standing on the extreme outer end of the arm, and although it does not seem reasonable, this was accomplished with six natives on each windlass and they did it easily. [These were designed to be operated by eight men each.]

"In erecting we invariably backed up the traveler, picked up two bottom-chord sections at the same time, ran out the traveler, and lowered both into place at once. And here a word about the traveler for the erection of viaducts where the girders have to be shipped in sections and erected on the cantilever plan, which is certainly the best way for countries where the material has to be loaded and unloaded several times without the proper equipments. This traveler is superior to a one-boom derrick car, as with it you invariably pick up and carry out two members; this traveler can be run to and fro with a locomotive the same as a derrick car, which I am doing now. I am speaking, of course, of a structure where the tonnage will permit the cost of erecting and dismantling this traveler and this cost is not excessive; for this reason, at a bridge of ordinary size it certainly pays to erect a derrick for handling the material. First erect this derrick, then use it for setting up and taking down the traveler. In this manner we took down the traveler, including donkey engine, lowering everything on cars ready for transportation, in six hours. The erecting and equipping generally took 15 hours. I used bull-wheels on all derricks and consider a saving of at least 30 per cent. in handling material can be effected by their use.



Traveler Completing Semi-Arch.

"Returning to the erection of the arch, the cableway for transferring one-half of the arch across the Barranca worked exceedingly well, a round trip being made in an average of eight minutes. The lowering and raising with the differential blocks was done quickly, as we blocked up our iron cars in such a manner we never had to lower or raise over 6 in. The anchoring of the cable was simple. There being an earth cut at either end of bridge within reach of the cable, we simply dug a trench across the cut 4 ft. below the grade and tunneled into both sides and inserted four 12 x 12-in. timbers. These reached into either tunnel about 7 ft. These tunnels were then filled with ties on top of the timber, the ties being firmly held in with wedges.

"Temporary towers with a height of 18 ft. were made of 4 x 12-in. timber, battered together at the top with 12 x 12-in. caps with a saddle of hard wood on top, well greased for the cables. When the cable was stretched the turnbuckles were opened to their full extent, allowing afterward a take-up of 4 ft. on each. The cable was tightened with luff-tackles composed of 14-in. double blocks and a 1½-in. diameter manila rope; the fall line of the luff-tackle was run to a nigger-head or donkey engine. In this manner the cable was tightened so that later when we sent over the heavier members all that was needed was about 2 ft. on the turn-buckles. I had intended, in order to save transporting material, to build a temporary traveler of timber for erecting the arch across the Barranca, but the cableway worked so well that I sent the large traveler over and saved money in the erection by doing so. The erecting traveler with the erecting engine was used to run the trolley to and fro, so as not to hamper the donkey engine on the derrick I used for loading material. The traveler was finally taken down with this derrick and the trolley lines for sending over the traveler were run to nigger-heads on this engine.

"After the completion of the arch the traveler was run under this same derrick and dismantled. On the return trip of traveler the temporary tower for the cable was picked up bodily with both booms and carried ashore and then taken down with the derrick. After all loading was completed this derrick was finally lowered. The donkey engine used on the derrick was set up on a flat car and throughout the erection of these bridges was never disconnected or removed, the car being simply spurred at each successive opening."

Making Final Top Chord Connection.

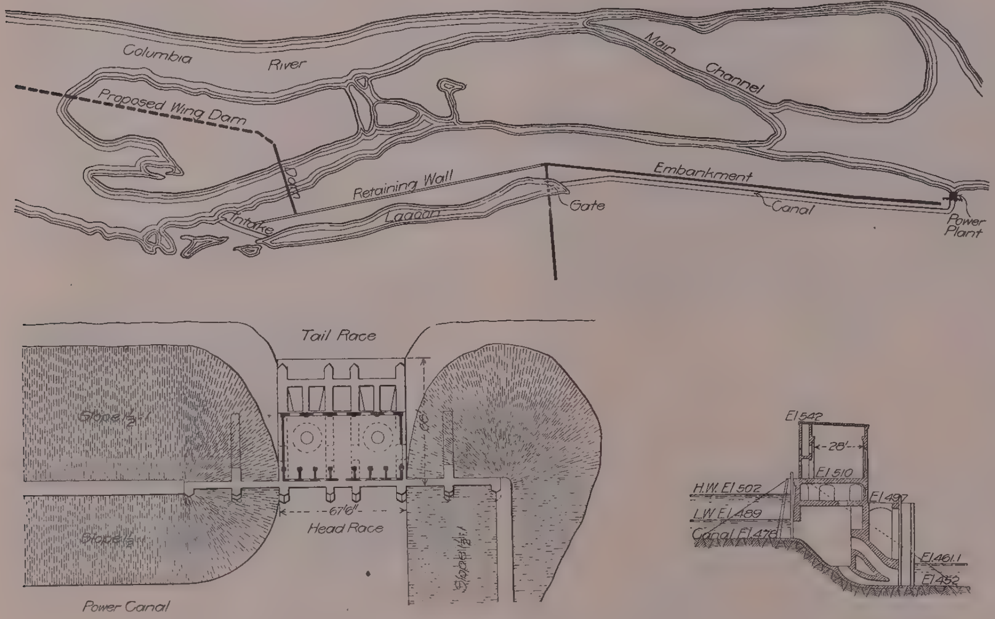
THE CORROSIVE ACTION OF SMOKE AND STEAM from locomotives on steel bridges was commented on in a recent report by Prof. Geo. F. Swain to the Massachusetts Board of Railroad Commissioners. A study of street railway bridges over steam railroads showed a number which had been greatly reduced in strength by this cause. Prof. Swain recommended careful and frequent examination, and stated that no paint is proof against this action and that the only safe and permanent plan appears to be to encase the steel in concrete or some other material that will not corrode.

Power Development at Priest Rapids on the Columbia River.

By C. L. Creelman, Resident Engineer.

The development of Priest Rapids on the Columbia River for water power is now being done by the Hanford Irrigation & Power Co., of Seattle. The work consists of a canal, an embankment about 2 miles long, a power house with a present capacity of 2,600 h.-p., with arrangements for an additional 5,000 h.-p. when required, a wing dam, 450 ft. long, across the channel just below the diversion point, and a system of gates in the canal about midway between the intake and power house.

Power Canal Opposite the Power Station.



Power Development at Priest Rapids, Columbia River.

At low water, there is a flow of about 12,000 cu. ft. per second through the channel at the intake. Part of this is diverted through a 140-ft. channel, 700 ft. long, into a natural lagoon, 1 to 7 ft. deep, 200 ft. wide and three-quarters of a mile long at low water. The gate line is located at the lower end of this lagoon at the same point where it is drained by the canal. To obstruct the channel at this place, it was necessary to build an embankment 1,900 ft. long, including gates, which will result in the inundation of a large area of land during high water.

The gates are of the butterfly type, 18 ft. long and 7 ft. deep vertically. When closed, they have a batter of 3.5:5, or about the same as the planking, which extends 12 ft., vertically, above the gates and is supported by bents 18 ft. apart. The gates swing on a horizontal shaft supported by three low bents. A continuous cable attached to the top of the gates passes through a pulley at the base about 7 ft. to the downstream side and thence to a windlass on the top of the bents and back to the top of the gates. By operating the windlass, the gates are pulled down to a horizontal position to open, and by reversing the windlass they are raised slightly, when the excess pressure below the shaft, assisted by the current, closes them tight. There are 10 gates of the above dimensions and one pad gate.

The canal between the lagoon and the power house has a grade of 0.0002 and is 67 ft. wide, except for a short distance in the rock, where it is only 60 ft. The side slopes are 1½:1. There are about 175,000 cu. yd. of excavation, nearly all of which is earth and coarse gravel, and this was handled by a 70-ton Atlantic shovel, 36 cars of 3 and 4 cu. yd. capacity and two dinkeys.

The first 4,000 ft. of embankment below the intake has a timber bulkhead on the river side with the embankment 8 ft. wide on top and a 1½:1 slope on the canal side. The posts supporting the bulkhead are 8 x 10 in. Washington fir, set 1 ft. in bedrock and anchored by inch rods to deadmen buried in the embankment, and are 8 ft. apart. The sheeting is 5 x 12 in., 4 x 12 in. and 3 x 12 in. and 16 ft. long. The remaining length of the embankment, 6,000 ft., is 8 ft. wide with 1½:1 slope both ways, the river side being covered with a layer of loose rock, 6 ft. wide at the base and tapering to a point near the crest.

All of the embankment is composed of canal excavation and, as before stated, the bulk of this is coarse gravel. The heavy winds have blown the sand and volcanic ash from the surface so that the entire mass has the appearance of a stone wall. It is quite probable that there will be considerable seepage through this embankment, yet it is too heavy for seepage to destroy and it is expected that the sediment deposited during the months of May and June will seal and strengthen it materially. Moreover, there is at all times a great deal of moss floating in the river, so that a timber or a rock submerged will be entirely covered with this substance in three or four weeks, and it is expected that this will also serve as a preventive of seepage.

The power house is about 67 ft. square at the foundations, and owing to the extreme fluctuations of the water level of the river, it was necessary to place the generator floor 58 ft. above the lower draft tubes. The flat concrete roof is 32 ft. above the generator floor, giving the building a total height of 90 ft. The head race wall is extended 50 ft. on each side of the building providing for four additional units which may be installed in the future as needs demand. The lower draft tubes are 11 ft. below the low-water mark. The excavation for the entire building consisted of 2,000 yd. of solid rock and 6,000 yd. of earth. This was all done by hand and required nine weeks to complete. The first forms for the concrete were placed Dec. 15, 1907, and there were 3,300 yd. of concrete in place on Feb. 20, 1908. The sand and gravel were screened in a pit about 500 ft. from the building and drawn up an incline in 2-yd. cars to the mixing platform. The mixing was done with a Foote batch mixer of ½-yd. capacity, and a daily average of 80 yd. was maintained except when the forms were complicated or when the mixing of concrete was prevented by inclement weather.

The minimum effective head is 18 ft. and the maximum 27, according to the stage of water in the river. The hydraulic and electrical machinery has been furnished and is being installed by Allis-Chalmers Co.

The wing dam is built of 8 x 12-in. timbers in sections 12 ft. square on top with a batter of 1:2 on the upstream side. Six 12-in. planks are placed in the bottom to keep rocks from passing through. A section is built on that portion of the dam which is completed and is built high enough so that when sunk in position, the top of it will stand above the water. Then by the use of a cable, which is anchored about 700 ft. upstream, with a tackle attachment at the dam, the section is pulled into the water, floated to place and filled with rock. This system has worked very well, although the irregularities in the river bed have presented some difficulties, yet the upper 4 ft. are above the present stage of the water which gives opportunity to level and line the top part. The greatest depth encountered was 14 ft. and that for a short distance only, the mean depth being less than 9 ft. About 70 per cent. of the dam has been completed and the remainder will be in water that is less than 5 ft. in depth.

By extending the wing dam up along the island which divides the main channel from the one on which the dam is being built, the head at low water could be increased 2 ft. very economically and, of course, could be increased indefinitely by extending it farther up in the river; however, this is a problem to be studied as the demand for power increases.

The Suez Canal Receipts during last year amounted to £4,638,773, as against £4,326,475 in 1906, and £4,554,671 in 1905. The tolls now charged are less than those in force in 1905.

The Erection of Hunt's Point Road Bridge.

Hunt's Point Road, in the Bronx, New York, is carried over the tracks of the Harlem branch of the New York, New Haven & Hartford R. R. on a deck plate-girder bridge about 132 ft. wide over all, with eleven longitudinal girders, 8½ ft. deep and 105 ft. long, spaced 11 ft. and 16 ft. apart on centers and connected by 15-in. transverse I-beams about 39 in. apart, with their top flanges nearly flush with the top flanges of the main girders. After the concrete abutments were built an excavation was made about 11 ft. deep between them with a steam shovel and carried down to grade, for the new alignment and tracks were laid there, on which were delivered the girders. The girders were unloaded from the cars by a derrick with a 62-ft. 30-ton steel boom erected in the cut alongside the track. It lifted the girders with hooks engaging their top flanges near the center of gravity and placed them, parallel to the axis of the bridge, on transverse rails, blocked up 3 ft. above the abutment seat.

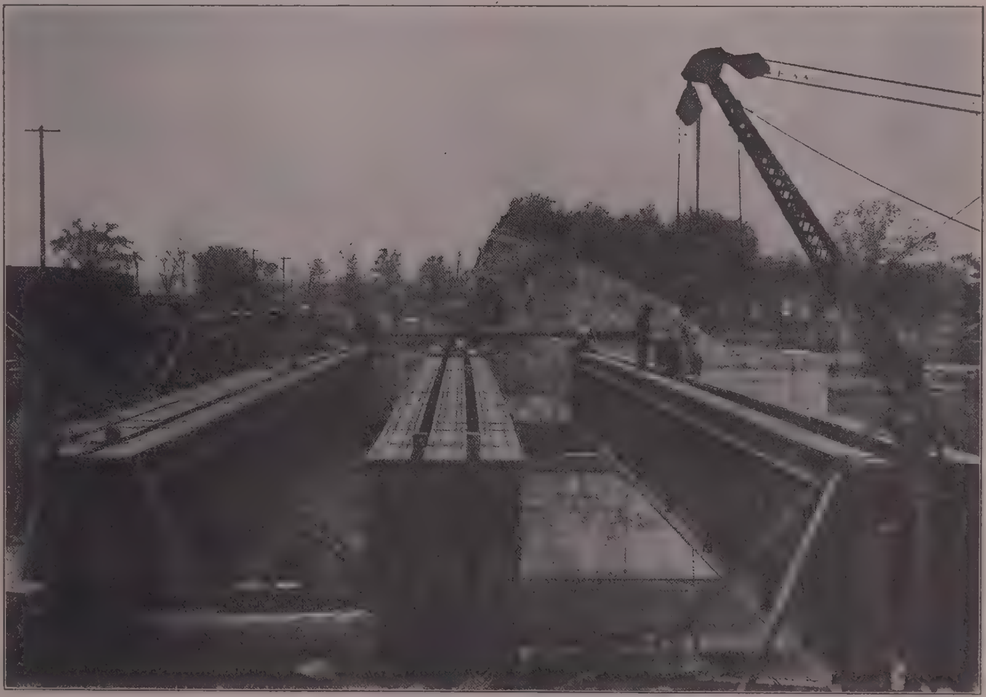
Finished Bridge and Low Level Track on Which Girders Were Delivered.

The girders were skidded to approximate position on the rails and the floor beams, transverse bracing, and lateral members were assembled and riveted up in two longitudinal halves. The girders overhung the rail bearings about 18 in. at each end and in these spaces wooden blocks and wedges were set on top of the cribbing and released the rails which were removed together with the two upper courses of cribbing. The plans provided for the alternative use of 40-ton hydraulic jacks with a closed height of 16 in. or less, to be used instead of the wedges for releasing the rails, but as the jacks were not readily available the work was done by wedging.

The cribbing on the abutment seat consisted of a lower course of three 12 x 12-in. continuous timbers, distributing the load over the full length of the abutment seat, a second tier of 12 x 12-in. timbers 3 ft. long, transverse to the first tier, and a third tier consisting of a single 12 x 12-in. timber parallel with those in the first course and concentric with them, to which the rail was spiked. After the removal of the rails and the two upper courses of timbers, vertical 12 x 12-in. posts about 8 ft. 9 in. long were seated on the lower course timbers close to each main girder and supported horizontal 12 x 12-in. white oak timbers, about 5 ft. long, nearly parallel to the main girders with their upper surfaces flush with the bottom flanges of the floor beams. The wedges under the ends of the main girders were then slacked off, transferring the weight of the bridge to the vertical post.

Longitudinal blocking pieces were fitted under the ends of the girders outside of the vertical posts and 60 and 100-ton hydraulic jacks were set under the girders adjacent to the posts and operated to release the latter, which were removed.

The girders were then jacked down about 18 in., removing the blocking to correspond, but always maintaining it within an inch of the girder flange to prevent any serious drop in case of failure of the jacks. When the girders were down within about 2 in. of their final position all of the safety blocking was removed from each successively, leaving the ends supported only on the jacks while the cast pedestals were inserted on the abutment seat and finally the girders lowered to permanent bearing on them. The longitudinal positions of the girders were determined and maintained by wedging and blocking them about 5½ in. clear of the back wall.



Girders of Hunt's Point Road Bridge in Temporary Position on Abutments.

One-half of the girders were first lowered to position at the expansion end and then the remaining girders were lowered at the same end, after which the fixed ends of the girders were similarly lowered in two successive operations. The total weight of the steel superstructure was about 1,260,000 lb., and it was erected, assembled, lowered and riveted up complete by a gang of about 12 men in about 48 working days.

The bridge was designed and its erection supervised by the engineering department of the railroad, Mr. Edward Gagel, chief engineer, and Mr. W. H. Moore, engineer of bridges. The superstructure was fabricated and erected by the Pennsylvania Steel Co., Steelton, Pa.

Raising a Carnegie Blast-Furnace Plant.

At New Castle, Pa., the waters of the Shenango River are frequently backed up by floods in the Ohio River so as to overflow the blast-furnace plant of the Carnegie Steel Co., and it was finally deemed necessary to raise the latter about 20 ft. in order to avoid danger and interruption from this source. One blast furnace, about 30 ft. in diameter and about 100 ft. high, weighing probably 500 tons, was raised about 25 ft., and one hot-blast stove, 20 ft. in diameter and about the same height, filled with brick and weighing about 1,100 tons, was raised 21 ft. The steel hoist adjacent to it, about 150 ft. high and weighing 200 tons, was also raised at the same time. The dust catcher, hot-blast main and gas main, all of them with steel frames or shells lined with brick, were also raised. The gas main, 5 ft. in diameter and 250 ft. long, was raised very carefully and continuously to avoid any injury or cracks.

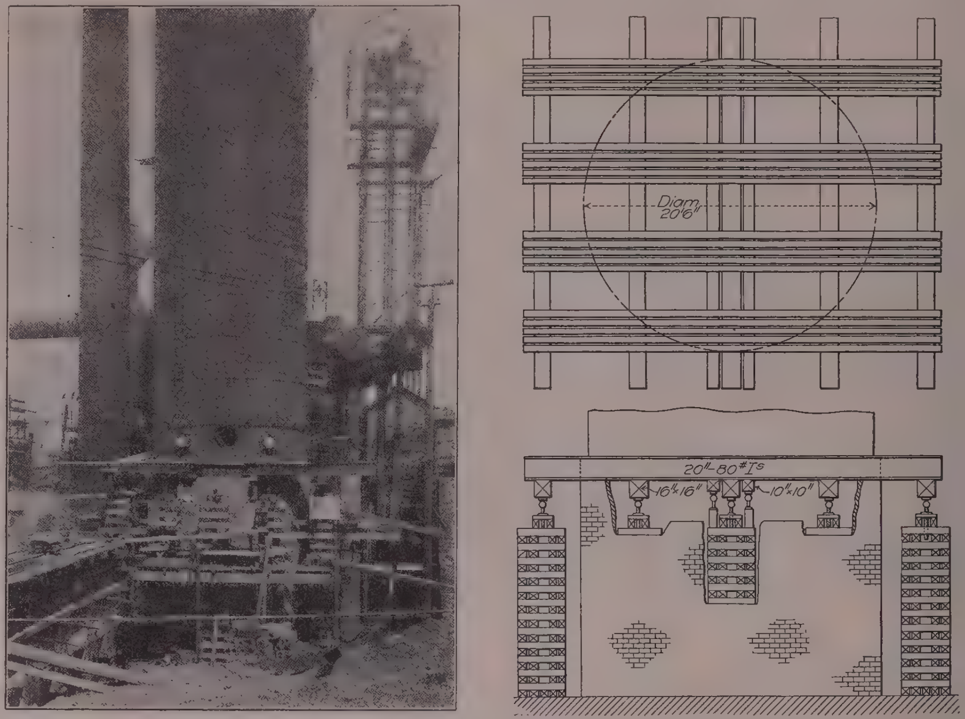
The stove was seated on a masonry foundation, 20½ ft. in diameter at the surface of the ground, and at this level operations were commenced by a force of about 20 men with chisels and sledges, who cut away from the exterior of the brickwork, inserting 5-ton jack screws in 8-in. drums as fast as the brickwork was removed, thus eventually entirely cutting away a height of 3 ft. from the top of the foundations and almost completely filling this space with about 1,000 5-ton jacks to which the entire weight of the stove above was thus transmitted. The rows of jacks were so arranged that twenty 20-in. 80-lb. I-beams, 30 ft. long, could be inserted between them and supported by other jacks on cribbing. The weight of the stove being transferred to the beams, the jacks outside the beams were released and removed.

The I-beams were arranged in four groups of five each, and each group was supported on five transverse lines of 16 x 16-in. Oregon pine timbers about 34 ft. long and about 6 ft. apart. Under these timbers the jacks were set as close together as possible on cribwork built up from the old foundations. Men passing through the alleys between the beams operated the jacks and raised the stove. The jacks had a stroke of 15 in., allowing the crib to be built up at each operation with two courses of 6 x 8-in. timber laid flat. The lines of cribs were so arranged as to enable part of them to be removed while the remainder supported the stack.

At first the two sets of timbers adjacent to the center set on each side were removed and the two corresponding side sections of brickwork were built up to a height of about 10 ft., after which the weight of the stove was transferred to them, the center group of jacks and cap timbers were removed and the center section of the brickwork was built up to a height of 15 ft., 5 ft. higher than on the sides, the load again transferred to it, the side beams replaced, and so on. By this means the new brickwork was built up as a solid cylinder 20½ ft. in diameter and 24 ft. high, to the new level of the base of the stove.

The blast furnace is supported on a circular row of columns, each of which is seated on the center of a segment of a circular cast-iron bedplate covering the top of the masonry foundation. The furnace was shut down and the lining removed, the upper part of the foundation masonry was removed in successive sections and jacks were inserted and the weight transferred from them to I-beam needles and alternately from the latter to alternating center and side sections of underpinning brickwork, as in the work already described.

The work was accomplished by an average force of 25 to 30 men in six weeks. It was designed and executed by the John Eichleay, Jr., Co., Pittsburg, Pa., Mr. J. P. Eichleay being in personal charge of the work. Mr. John S. Oursler was superintendent in charge for the Carnegie Steel Co.



Underpinning and Cribbing used in Raising a Blast-Furnace Stove.

A Large Pile Protection Contract.

One of the most interesting contracts for pile protection awarded for some time is that given to the Lock Joint Pipe Co. by the Charlotte Harbor & Northern Ry. Co., which is building a line primarily for handling phosphate rock from the mines of the American Agricultural Chemical Co. to deep water. At present a 62-mile line is in operation between Arcadia, Fla., and Boca Grande, where large wharves and terminals will be built, while a 60-mile extension from Boca Grande to Plant City is under construction. The wharves and terminal improvements require a large amount of piling in salt water, and this as well as the trestles across the shallow inlets would quickly be destroyed by mollusks were they left unprotected. As the cost of this piling runs to a large figure, it was considered good business economy to protect the timber in a permanent manner. Some idea of the character of the work is shown by the accompanying picture of the Gasparilla trestle, which is 2 miles long and has 3,350 45-ft. piles. It will be noticed that the protective covering is being applied while the trestle is in use, which is a feature of this system of construction that is one of its advantages.

The Gasparilla Trestle, Two Miles Long, on the Charlotte Harbor & Northern Railway.

Although the lock-joint pipe was described in this journal when it was first placed on the market, a brief explanation of it is given here to indicate its applicability for such work. Each length of pipe is formed of two concrete longitudinal halves, which fit together in two longitudinal joints of special form. After the halves are placed together, a spline or key is inserted in each joint, which locks both halves together into a single length of pipe having the general shape of an ordinary bell-end sewer pipe. The half-pipes on this work are made on a beach near the trestle, using an ingenious molding machine built specially for the purpose. They are cured in the open and each piece is marked to designate its place in the work.

The pieces are taken in boats to the working scows moored alongside the trestle, and are there locked about the piles, one over another, until the pile is protected from the mud line to above water. The pipes fit loosely about the pile and the bottom one is lowered by ropes as each successive length is put in place and the joint with the lower one is made. The weight of the pipes causes the lower section to sink into the mud somewhat, thereby sealing that end, and the annular space between the pile and the pipe is then filled with fine sand. So long as this sand remains in place, the timber is safe, for the teredo cannot live unless one of its extremities is in the water. In case the bottom is scoured away at any place, the pipe covering settles down farther, and it is only necessary to add another length at the upper end. If one of the half-pipes becomes broken from any cause, the pipes above can be lifted up, a new piece inserted and locked, and the protection is as effective as ever. The condition of the protection can be inspected by observing the condition of the fine sand between the pile and the pipes. If it has disappeared, there is a break somewhere which has allowed it to run out.

Repairing Foundations with Grout and by Divers.

The many old buildings and other masonry structures in Great Britain have presented a class of problems of a rather unusual nature in connection with their maintenance, and at a recent meeting of the Royal Institute of British Architects, Mr. Francis Fox read a paper explaining some of the methods followed in repairing their foundations. The first of these methods consists of grouting operations which were developed by the late James Greathead. According to Mr. Fox, some 40 years ago a large railway bridge over the London & South Western Ry. had a pier cracked from top to bottom in consequence of carelessness on the part of the masons fixing the bed stones for the column. This was so badly injured that it had to be rebuilt, and fear was entertained that all the other piers might prove to be suffering from the same defect. To avoid reconstructing the entire number, grouting was adopted, and, by applying a funnel and pipe of considerable height, cement grout was forced by the hydrostatic pressure into any cavities which existed. Thus an accident was averted at a cost of £5 or £10, and a probable expense of several hundreds was avoided.

Another instance was that of an ordinary arched bridge to carry an express line of railway over a roadway which was under construction. The centering was in error, taken down too soon, with the result, that the abutments were pushed right and left on the masonry joints, making an unintentional plinth on both sides, and cracking the arch in several places through its entire width. The grouting system was applied as an experiment to avoid an expense of £500, which would have been necessitated by the reconstruction of the bridge. After an outlay in labor and cement of £27, the structure was completely repaired (except that these unequal plinths remain), and it has for 25 years carried some of the heaviest express locomotives traveling at high speeds.

Unless height can be obtained for the funnel and pipe, this system cannot be applied, and thus in cellar and tunnel work it could not be used. Hence it was that Mr. Greathead proposed to abolish the funnel and vertical pipe, and in its place to apply compressed air. The grouting machine he designed consists of an iron receiver or reservoir into which, by means of pumps, air can be forced under any pressure up to 100 lb. to the inch. This receiver is connected by a flexible tube to a "grouting pan," which is a churn furnished with a handle and spindle to which are attached arms or beaters. The proper proportions of cement and water, and in certain cases sand, are then placed inside, the lid screwed down, and the contents churned up into the consistency of cream. This is now ready to be blown into the crack, the mouth of which on either side of the wall has meanwhile been clayed up to prevent the grout from escaping. The compressed air is then admitted to the grouting pan, and so soon as the necessary valve is opened the contents are discharged into the wall.

One of the first applications of this system was carried out by Mr. Greathead in the case of some extensive wine cellars. In consequence of some adjacent excavations, these cellars had been cracked; and although the injury to the building was not important, still the expense which would have been incurred was very great. These cellars contained costly wine, and it was estimated that the mere transference of it to other cellars would have depreciated its value to the extent of some £10,000. Hence it was essential that, if possible, this should be avoided, and the grouting machine was applied. So successful was the result that not even a single bottle of wine had to be moved, and the entire cost of the work was only a few pounds.

A year or so later a summons from the Mayor of the ancient city of Chester necessitated a visit to examine the towers and walls of those interesting remains, partly of Roman, partly of mediæval times. Evidently one of the towers was in jeopardy: it was cracked from top to bottom, and the various parts were moving in opposite directions. Whether the foundations were in fault, or the walls were weak, it was impossible to say; but the first thing to be done was to shore the tower with timber to prevent a collapse. The grouting machine was then applied, commencing at the base of the tower and gradually working upwards. By this means the cracks were filled with cement, and the walls were turned into monoliths; all the bulging portions, the old stones and worn surfaces were left untouched, thus preserving the artistic and archæological interests. Then the foundations could be examined, strengthened and underpinned, and everything put on a satisfactory basis. Although years have elapsed since these repairs were effected, no further cracks nor movements have taken place. The ancient rampart consisted of two badly built walls, the space between filled up with gravel, rubbish and loose stones. This was thoroughly saturated with cement and the movement was arrested.

One of the most interesting applications of the grouting machine has been at Winchester, where very serious subsidence had taken place in various parts of the splendid cathedral, that in the presbytery amounting to nearly 2 ft. 6 in. The outer walls and buttresses had gone seriously out of the perpendicular, while the beautiful groined arches were distorted in form and disintegrated in character, and alarm had been caused by the fall of some stone from the roof. Mr. T. G. Jackson, the diocesan architect, had sunk a trial pit some few yards distant, and had discovered a bed of peat 8 ft. deep below the clay and resting upon a fine solid bed of flints and gravel, into which he had bored to some depth to prove its solidity. An excavation 5 ft. in width was then made adjacent to the south wall, in which, at a depth of about 8 ft. below the turf, the bottom of the masonry foundation was reached. It was discovered that the wall had been built on logs of beechwood; in fact, whole trees placed side by side horizontally, and these again, in their turn, rested in some instances on a second layer of trees. These timbers were to some extent rotten, but in other cases the heart was sound and good as ever. The curious feature was, that even the rotten portion showed no signs of squeezing nor flattening under the weight of the wall. The level of the underside of these timbers coincided at that date with that of the water in the subsoil, although this level varied with dry and wet weather. This probably accounts for the timber decaying, as, in consequence of the draining of the city by the Corporation, the level has been permanently lowered, and the timber, which doubtless was just below water level, has of late years been alternately wet and dry, and has, consequently, to some extent, decayed. Beneath this timber a bed of chalky marl, in places 6 ft. in thickness, was found to exist; and as very little pumping was required to keep the excavation dry, and the water came away clear and pellucid without any sand or deposit, the work was able to be proceeded with by means of a hand pump. The bed of peat proved to be almost impervious to water; but when within about a foot of the bottom (the entire thickness proving to be from 5 ft. to 8 ft. 6 in.) the lowest layer was suddenly burst up by the influx of a great volume of water from the gravel bed below, under considerable head. This was due to the water in the adjacent river, and in the course of a minute the whole pit was filled with water up to the original level. Pumping was plainly inadmissible, the use of compressed air was inapplicable, screw piles and caissons were considered and rejected, a slab of concrete on which to float the cathedral was impossible, and finally it was decided to employ a diver, by which means the work could be done quietly and without vibration. A telegram brought down two experienced men, and by their aid the excavation, in lengths of 5 ft., was finished, after which Mr. Fox descended in the dress to examine the bottom. This proved to be a hard flinty gravel, quite excellent, and as this overlies the chalk, no better foundation could be either secured or desired.

The pits are absolutely dark, owing to the water being thick with peat, and no artificial light is possible; consequently the whole work of repairing is done, not by sight, but by feeling. So soon as the peat is excavated the bottom is covered over with bags filled with concrete, carefully and tightly trodden in all round; these are then slit open and another layer of bags placed on the top. These again are ripped up, and so on for four courses in all. The grouting machine can be used, the pipe being directed by the diver, but in this case all the chinks and crannies between the bags are filled by hand with cement concrete lowered down to him in buckets. Thus this mass becomes practically a solid rock and seals down the flood of water from the gravel, enabling the excavation to be pumped dry. Concreting is then continued, either in bulk or in block, until a considerable height is attained, and upon this blocks of concrete or brick in cement are carried up and tightly pinned to the underside of the old masonry, constituting the original foundations of the cathedral. When all these excavations or pits are completed, the walls of the presbytery will be practically standing on a bed of rock, instead of on compressible peat, and great credit is due to the diver, Mr. Fox said, for the excellent manner in which he has executed this most responsible work.

The sequence of operations is as follows: 1, shoring up outside and inside of walls and vaulting; 2, grouting the walls, arching and buttresses; 3, the underpinning of the walls down to the gravel. When the above is done, the cracks will be cut out and repaired, and steel tie-bars will be fixed in different parts of the fabric.

It has now been ascertained that almost the entire cathedral stands on peat, which must be excavated. The south transept is over 4 ft. out of the perpendicular, and cracks of the gravest character are found in all directions. The most serious fact is that the cathedral is sinking, due to the further compression of the peat in those places whence it has not yet been removed. "Telltales" or fillets of cement are placed across the cracks to give warning of any movement taking place, and except in those parts which have already been underpinned, these cement fillets are broken through, in many cases within a month. In fact, the cathedral is doomed unless it is underpinned, and that without delay. Further extensive investigations will have to be made and repairs effected, both in the transept walls and main north and south aisles of this splendid cathedral, involving heavy expense.

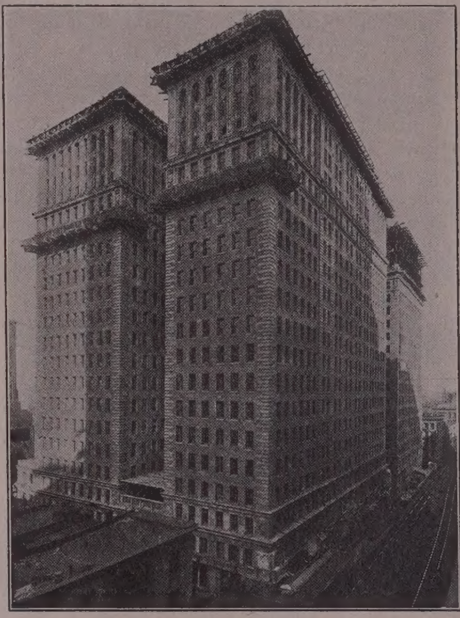
The ancient church of Corhampton, near Bishop's Waltham, in Hampshire, repaired by Mr. Jackson, is another satisfactory instance of the application of the grouting machine. This Saxon church, 1,300 years old, was in a sadly dilapidated condition. In the west gable there were three large cracks, one from the ridge to the ground wide enough for a man's arm to enter; another nearer the side wall, wide enough for the insertion of his head, while at the northwest angle the Saxon work threatened to fall bodily off. The mortar of the walls had perished through age, and the ivy had penetrated into the interior of the church in every direction. It would have been unsafe to attempt any examination of the foundations for fear of bringing down the whole fabric; consequently the grouting machine was applied all over the building. The "grout" escaped at every point, and it occupied the attention of the masons both inside and outside to stop it promptly by dabbing red clay onto the openings from which it was running. By the time the walls had taken all the grout that could be forced in, the church was practically a red building, both inside and outside, from the extensive use of this red clay. The cracks were in places so wide that they had to be specially treated before commencing to grout them, and the clay was so arranged as to extend into the crack about an inch on both faces. After the operation had been completed and the cement had set hard, the clay was removed and the interior was found to be filled with adamant, but as it did not come within an inch of the face of the wall, sufficient depth was left for fixing the flint work outside and tiling inside. The result is that no trace of the cracks is visible, and after this treatment of the walls they are stronger and better than they ever were. Subsequent steps were then taken to examine and, where necessary, to underpin the walls, and we have the satisfaction of knowing that these efforts have saved the church.

Holy Trinity Church, Hull, is the most recent instance of the application of this system, but the difficulties were as great, or greater, than any of those already described. This magnificent church, one of the three largest in England, was built soon after A. D. 1300, at which date the foundations of the tower were laid. The choir was completed in 1361, the nave in 1418, and the upper portion of the tower in 1520. The church consists of a fine nave of eight arches on each side, with side aisles, the choir of five arches and also with side aisles; a transept with the handsome tower in the middle standing on four massive piers, each one cruciform on plan. The weight of the tower is 2,800 tons, equivalent to 700 tons on each pier. For some time past signs of serious settlements had shown themselves in the arches and piers surrounding the tower, and these had been under the observation of the architect of the church, Mr. F. S. Brodrick, diocesan surveyor. These movements had caused considerable cracks, and portions of masonry had from time to time fallen, the most alarming of which was that of a large corbel carrying the ridge of the choir roof on the eastern face of the tower. The piers of the nave, which for their height are very slender, and are each carrying a load of 75 tons, exhibited serious deviation from the perpendicular, being from 6 to 7 in. out of plumb, and the subsidence of the tower had caused the joints of the shafts to open on one side and to crush on the other. These movements were going on at a somewhat alarming rate when Mr. Fox was called into consultation. A tradition existed that, as the town of Hull stands on a bed of clay overlying a deep bed of silt, the tower was built on a raft of timber, but this required investigation. On making a careful survey of the building in conjunction with Mr. Brodrick, the conclusion was reached that, from some cause or other, the tower was slowly sinking, and in so doing was pushing all the arches at the west end towards the west, and all the arches at the east towards the east. The first thing to be done was to strut and cross-brace the arches and columns to prevent the possibility of a collapse; next to examine the brickwork in the spandrils of the arches adjacent to the tower. These were covered with plaster, but, on this being removed, serious cracks were found, showing that the brickwork was being dragged down by the pier.

A hole was then made in the floor of the church, and, as expected, a timber raft of horizontal oak baulks crossing each other at right angles was discovered. The upper layer had been reduced—by rot—to a powder resembling coffee-grounds, and innumerable worms known as "eel worms," from ⅛ in. to ½ in. in length, infested the material. The destruction of the upper layer was practically complete, and the lower layer of timber was decaying. The masonry overlying this timber was cracked and flaked in all directions and most seriously injured, and a very interesting and unexpected discovery was made. A stone seat or bench table was found surrounding the pier of the tower, and partly in consequence of the sinking of the tower, and partly as a result of the floor being raised at some period, this seat is now below the tiling, and completely out of sight, and all record of it had been lost. Stone seats of this character are said to have given rise to the expression "the weakest go to the wall." This is generally considered to imply that in the rush and race of life the strongest pass by the weakest, who are ground against the wall. However, it is said to mean that in mediæval times, when services were held in the body of the churches (as in the cathedrals and churches on the Continent of to-day), no sitting accommodation being provided, the strongest had to stand, but the weakest would find seats if they went to the wall. Certainly this is the more pleasing interpretation of the saying.

Pending the decision as to the very difficult problem involved in this parish church of Hull, for the removal of the decaying timber and crushed masonry, all of which had to be replaced, the grouting machine was freely used for pumping or forcing in cement into every cavity and crevice, and for filling up all the voids left by the decayed timber. Beneath the columns of the nave vertical piles, probably of larch, were found, but in some instances the timbers had gone into powder, leaving only the form of the timber impressed in the clay, so that where a pile formerly existed only a cylindrical hole similar to the molded form for casting a pipe remained, and at the bottom of the holes was a mass of the before-mentioned "coffee-grounds."

The contractors are Messrs. Thompson, of Peterborough, whose representative, Mr. Ball, has carried out the difficult and often dangerous operation with great skill. One pier of the tower was dealt with at a time, and the greatest care had to be exercised. An excavation 24 ft. in length by 6 ft. in width, and to the same depth as the old work, was made clear of the pier, and on both the east and west sides, and was filled with concrete in which were placed grillage beams in order to distribute the eventual weight over the whole area. A hole 2½ ft. in depth and about 9 in. in width was then carefully cut or "jumped" through the masonry of the pier, and a steel girder, 24 in. by 7 in., was threaded through the hole and rested on the grillage beams in these concrete blocks. In order to prevent subsidence, due to the deflection of the girder when it received its load, steel wedges were driven in under the end of the steel beams, thus giving the initial deflection, and avoiding by this means all sinking of the pier. The girder was then built into position with blue brick in cement and was carefully grouted up. A second, third and fourth steel beam were in due rotation placed in position, and in this manner the load was quietly and safely transferred from the decaying wood beams on to the steel girders. After this the old cracked masonry and rotting timbers (which were found to be snapped through) were removed, one-fourth part at a time, from beneath the pier, and their place filled up with concrete in cement, with the result that to-day each pier stands on about 560 sq. ft. of solid concrete instead of on the old defective foundation. As soon as the four piers of the tower were secured the columns of the nave were taken down, one at a time, and rebuilt in vertical position with so much of the old masonry as was available, but in consequence of the transverse strains brought to bear upon them about two blocks out of twelve were so fractured as to be useless.



Hudson Companies' Terminal Buildings.

Deep Water Diving can be carried on with safety to a depth of 210 ft. provided proper precautions are taken and suitable appliances used, according to a recently published report of the British Admiralty Committee appointed to investigate the subject.

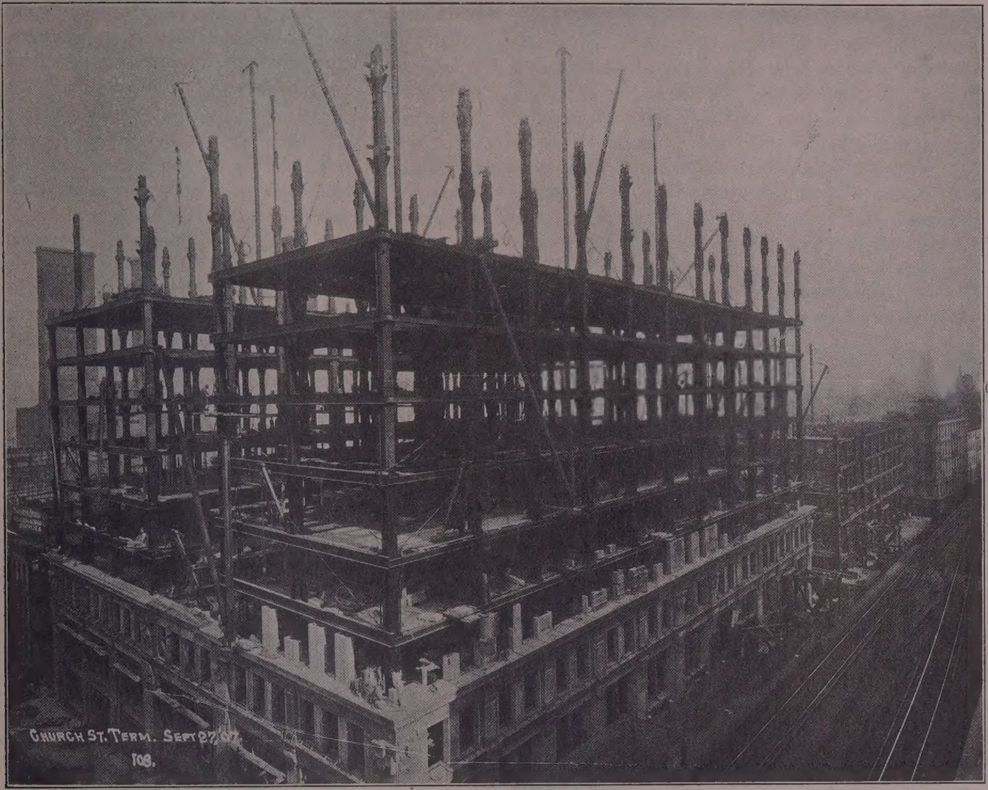
The Construction of the Hudson Companies' Buildings, New York.

One of the most interesting and probably the largest although not the tallest of office buildings, is that now nearing completion for the Hudson Companies, New York, which will serve as an important terminal for suburban passenger traffic and provides a large amount of office space in the congested downtown district, advantageously located near the principal ferries and transportation lines and very close to the financial district. It occupies two city blocks between Cortlandt St. and Fulton St., on Church St., and covers an area of about 210 x 435 ft. horizontally and extends vertically about 300 ft. above the curb and 76 ft. below it from the top of the superstructure to the lowest floor. It is, of course, of fireproof steel cage construction and the great loads from its 23-story columns are carried to rock or hard pan nearly 100 ft. below the surface by concrete piers sunk by the pneumatic caisson process.

The lower part of the building extends far below ground water level and the substructure occupies the whole undivided area and is enclosed by massive retaining walls proportioned to resist the very heavy external pressure from water and quicksand. The track floor, train floor, concourse, and upper and lower mezzanine floors below street level are carried under Dey St., and are chiefly devoted to the offices of the company, to equipment, and to passenger service required by its functions as the terminal of the Hudson River Tunnel and its connection with the New York Rapid Transit Subway, elevated railroad and New Jersey trolley lines. On this portion of the building as a base is reared the 21-story superstructure which consists of two structurally independent office buildings, known as the Fulton and Cortlandt Buildings and separated by Dey St., which with its sewer, conduits, mains, etc., is carried over the lower stories on a massive plate girder construction. Both the Fulton and Cortlandt Buildings are provided with large light courts giving them cross sections H-shaped in plan and they are essentially similar in arrangements, details, construction and appearance, are operated with the same equipment and mechanical installations and are connected by a second-story covered bridge or arcade across Dey St. The 213 x 170-ft Cortlandt St. Building contains about 26,000 sq. ft. of rentable area on each of the upper floors and the 156 x 154-ft. Fulton Building has about 18,000 ft., making in all about 900,000 sq. ft. in both buildings. The structural steel work was illustrated in The Engineering Record of Aug. 3, 1907.

The estimated weight of the building, including maximum live load is about 165,000 tons, about 25,000 tons of which is the weight of the structural steel work. The exterior walls are carried at every story by the framework and are of brick, faced up to the 5th floor with polished granite from the New England Granite Works and limestone from the Indiana quarries. From the 6th to the 16th floor they are trimmed with terra cotta and above the 16th floor they are faced entirely with terra cotta ashlar. The floors are of reinforced cinder concrete construction of the Roebling type with suspended ceilings on wire lath and the flat roof is of similar construction covered with hard glazed tile 1 in. thick and a finishing surface of Russian tile laid in cement mortar. Terrazzo floors are used in corridors, toilet rooms and public spaces, and the office floors have a yellow pine wearing surface nailed to 3 x 4-in. strips bedded in the concrete fill. Partitions are made with National Fireproofing Company's hollow tile, 3, 4 and 6-in. thick laid up in Portland cement mortar.

The columns and girders are fireproofed with the same material, 4 in. thick, enclosing air spaces which are not filled with mortar or grout but are left vacant for insulation. These spaces, adjacent to columns are extended to provide chases in which pipe mains and risers are run behind the terra cotta. All exterior sash and doors and those in the main corridors are kalamined and all other interior woodwork and trim is fireproofed by the electric and fireproofine processes. Wire glass is used for some of the exterior and court windows and the stairs have cast-iron frames and marble treads.



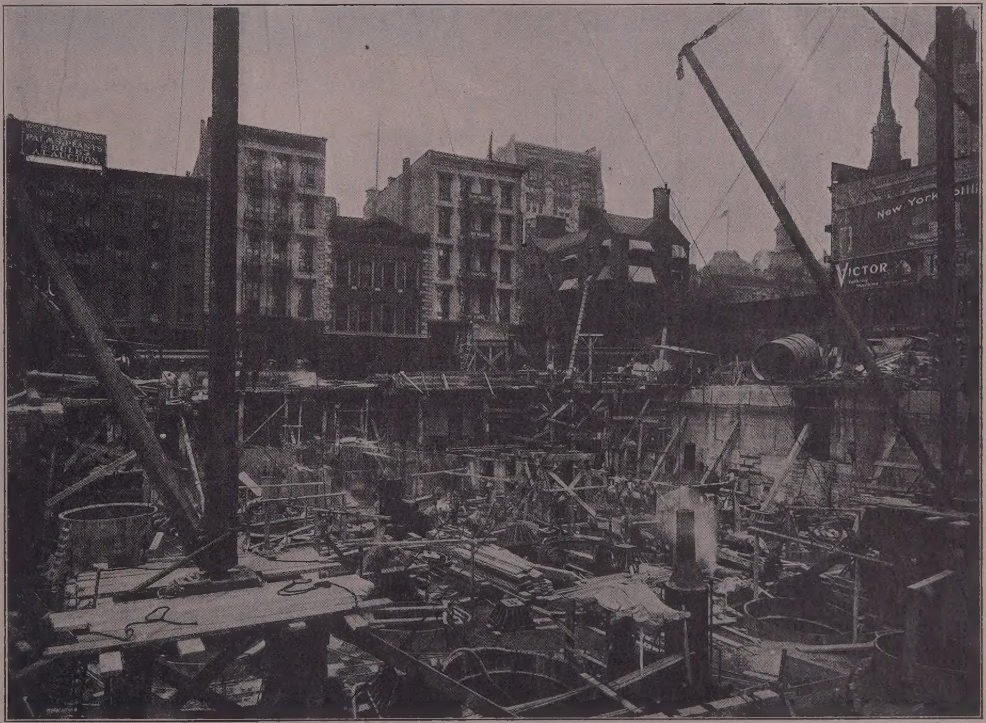
Steel Work; View from Church and Cortlandt Streets.

The building is lighted through 5,000 windows and by 30,000 incandescent lamps operated by dynamos in the lower story where there is an elaborate mechanical installation including a 1,600-h.-p. battery of steam boilers. There are 39 passenger elevators and complete installations for sanitary, hydraulic, electric and pneumatic service.

The erection of the steel work was commenced in April, 1907, long before the main excavation was completed. Wooden pyramidal towers about 18 ft. high were erected in the bottom of the excavation and on them four derricks were installed for the Fulton Building and six for the Cortlandt Building, located so as together to command the entire area of the lot and of the adjacent streets. They were of uniform size and rig, each having a 70-ft. mast and a 65-ft. 20-ton boom, eight 1¼-in. steel guys, and hoisting and topping lift tackles rove with 11 parts of ⅞-in. steel rope. Each derrick required a 9-man erection gang and on heavy work erected about 100 tons per day. Each derrick was operated by a double-drum Mundy hoisting engine and separate steam boiler, located on the concourse floor as soon as the latter was erected, excepting one derrick which was operated by a Lidgerwood electric hoisting engine.

The concrete piers were built in wooden cofferdams extending 45 ft. above their tops to the concourse floor, below which level the general excavation had not been carried when the steel work was commenced. The column loads are distributed over the surfaces of the concrete piers through very large cast-iron bases without the interposition, in many cases, of grillage beams and these bases, about 4 or 5 ft. square were lowered over 40 ft. by the derricks through the 10-ft. caissons, carefully located by transit lines and plumb bobs, wedged up about ½ in. to 1 in. to accurate level and grouted in position with 1:2 Portland cement grout. The first sections of the columns were seated on the pedestals and projecting a few feet beyond the tops of the cofferdam which had been cut down 2 ft. below the level of the concourse floor, permitted the beam and girder connections to be made just clear of the bottom of the general excavation, after which the erection was carried up in the usual manner.

As opportunity was afforded for excavation around the caissons the pit was gradually deepened until the train floors and track floors were successively reached, when the cofferdams were cut down a little below their respective levels and the beams and girders were lowered and connected to them. This method, of course, involved simultaneous excavation and erection and caused considerable congestion which was carefully and successfully handled and enabled much time to be saved in the construction of the building which was carried on rapidly above the street level while the work below it was steadily progressing.



Circular Cofferdams Ready to Receive Column Pedestals.

The 25,000 tons of structural steel was fabricated at the Trenton and Pencoyd plants of the American Bridge Co., shipped by rail and lighters to Pier 11, East River, and delivered thence to the building by trucks which were unloaded on all four of the circumscribing streets. This vast amount of steel, together with the much larger bulk of other building materials and corresponding quantities simultaneously trucked to another immense office building, erected in the immediate vicinity, together with the street excavations for the sidewalk vaults and retaining walls, caused a great congestion and disorganization in the vicinity of the building and made traffic on some parts of the street very difficult. Every effort was, however, made by the contractors to relieve the situation.

Heavy elevated platforms 12 ft. wide were built over the sidewalks on all sides of the building and served as usual both to protect the pedestrians and provide storage and unloading facilities for the stone and terra cotta work. During the early part of the construction temporary falsework platforms were built over the excavation at street level and permitted trucks to be loaded and unloaded without standing in the street. As soon as the beams and girders for the street floor were erected and the permanent floor built on them, exits and entrances were arranged in the different fronts so that all materials excepting steel were trucked inside the building and unloaded there without unnecessary street obstruction.

Steel for the upper tiers was delivered as erected and little or none was stored at the building from day to day. This system, was, however, not feasible for the lower tiers and about 8,000 tons of the heaviest sections of the columns and girders were piled up in the excavation before the erection was commenced. This material was carefully sorted and arranged to facilitate the simultaneous erection of the mezzanine, first and second floors, which were of very irregular construction and could not be handled independently.

Owing to the fact that the building is not exactly symmetrical, that none of the angles are right angles, that the dimensions in the Fulton and Cortlandt Buildings are quite different, that the street grade slopes considerably, and that the arrangement of the lower and mezzanine floors is greatly diversified by the stairs and entrances, the steel work and framing up to the second floor above street level is exceedingly irregular and complicated and the difficulties of erection were unusually great.

The two buildings together contain about 150 columns, with maximum cross section of 268 sq. in. and weights of 25 tons for single two-story lengths. The heaviest girders weigh 30 tons each and in the Fulton Building alone there are in the lower mezzanine floor 58 girders of 30 different patterns and a corresponding construction in the Cortlandt St. Building. Between the two buildings the street platforms, proportioned for a load of 1,400 lb. per square foot is made with the heaviest and deepest I-beams close together, carried on massive columns and double plate girders and supporting 18-in. concrete slabs.

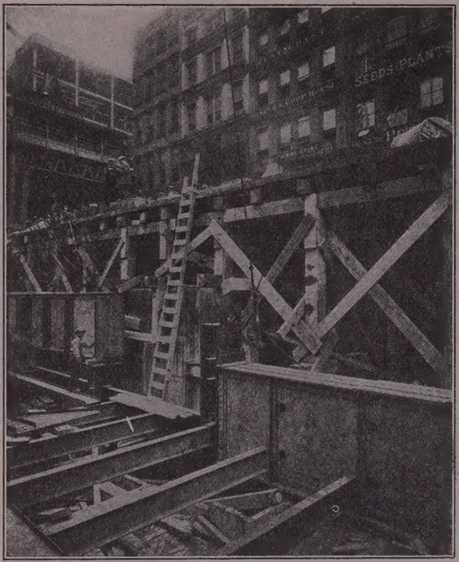
All of this steel work was erected by the derricks already described and after its completion they were carried up in the usual way with the successive tiers of the superstructure and completed the erection of the 21 stories above street level. The heaviest girders, 45 ft. long, were unloaded by two derrick booms and set by breast derricks; all the rest were handled by single booms. The weight of a typical upper tier of both Cortlandt and Fulton Buildings was about 1,000 tons and it could be erected in 4 days if the material was always in readiness which, however, was not the case. The derricks were raised in the usual manner every second story and were only out of service for about 3 hr. for each movement.

The derricks, especially those hoisting at long radius from the street, imposed very severe stresses on the framework and made it necessary to provide against the displacement of the columns. Special pains were therefore taken to secure those under the derricks and these, together with all wall columns, were X-braced in from two to four of the last erected stories by wire rope diagonals with turn-buckle adjustments under the constant supervision of a 6-man bracing gang.

Five Ingersoll-Sargent air compressors were installed on the second floor of the Cortlandt Building and delivered air under a pressure of about 110 pounds through two vertical 3-in. risers in each building. Outlets and flexible connections were provided at every story and operated thirty-four Chicago Pneumatic Tool Company's hammers and reamers, with which all field rivets were driven at a rate of about 250 per gang per day. The structural steel was erected by the general contractor with an average force of about 150 men and was completed Jan. 15, 1908.

The floor construction followed the steel erection as rapidly as possible and it was usually maintained about four tiers behind the latter It was commenced Aug. 6, 1907, and finished Jan. 17, 1908, with an average force of about 300 men employed by the Roebling Construction Co., sub-contractors. The granite and limestone work was commenced Aug. 17, 1907, and finished Oct. 31, by the contractor, Mr. Wm. Bradley & Sons, who employed an average force of 50 men. All stone was cut in the Brooklyn yard and was unloaded from trucks in the street by 16 derricks on the Cortlandt Building and 4 on the Fulton Building, which deposited it on the sidewalk bridges, from which it was hoisted to place and handled by a large number of hand-power breast derricks. Every stone was anchored by a 1½ x ¼-in. galvanized iron strap to the brickwork or by a 2 x ½-in. strap to the steel framework. The stones were set in Lafarge cement mortar with joints ⅛ in. thick, exclusive of the slots cut to receive the anchor bars.

About 5,000 tons of terra cotta were furnished by the Perth Amboy Terra Cotta Co., and were set by the general contractor, who commenced work at the 16th story Nov. 12, 1907, and completed it Feb. 10, 1908, with an average force of about 500 men. There are in the main walls about 15,000,000 bricks furnished by Sayre & Fisher Co., and laid by the general contractors with an average force of about 550 men. Above the stone work the walls were carried up about two stories behind the steel erection and were built from scaffolds supported by 220 hangers furnished by the N. Y. Safety Scaffold Co., and set about 8 ft. apart. These were equipped with steel ropes 100 ft. long and were operated by the masons from the scaffolds. The terra cotta work was set from heavier scaffolds supported on cantilever wooden beams projecting from the windows and braced at the outer ends to vertical pieces carrying tight board protecting walls about 3 ft. high which enclosed the scaffolds and afforded security to the workmen and to people below.



Heavy Girders in Substructure.

No universal system of inspection or checking of manufacturers' shipments was found necessary, but care was exercised to order special supplies well in advance and ordinary supplies about two weeks before they were required. Supplies were received from all four adjacent streets and all trucks were driven inside the building, where as many as 15 were sometimes simultaneously unloaded, the space being ample for them to turn around and depart through the same entrances through which they arrived. About 4,000 yards of sand and 200,000 bricks delivered through chutes to the concourse floor were kept stored there for emergency supply during the construction of most of the work. Floor materials and daily supplies were unloaded as close as possible to some of the eight Thomas & Buckley rapid hod hoists in the Cortlandt Building and six in the Fulton Building and delivered as required by wheelbarrows and trucks on the different floors. A stiff-leg derrick was installed in each building for hoisting floor materials and other woodwork.

The steam-fitting, hydraulic and sanitary work follows closely after the erection of the steel work and was commenced Aug. 14, 1907, when the riser lines were run adjacent to the columns inside the fireproofing. They were carried on with an average force of about 150 men each, employed by Thompson & Starrett and Wells & Newton, who were the contractors for steam-fitting and plumbing respectively. There are in all about 200,000 sq. yd. of plastering made with Keene's cement mortar, received dry mixed in bags. The work was commenced Nov. 25, 1907, carried on with an average force of about 200 men employed by the general contractor. The carpenter work and trim was commenced June 4, 1907, and has been carried on with an average force of about 175 men. The ornamental ironwork chiefly consists of the elevator and stair construction, and was commenced Aug. 15, 1907, by sub-contractor Ritchie, Brown & Donald, who employed an average force of about 80 men.

The sub-contractors were under the general direction of Mr. John Braid, superintendent for the Geo. A. Fuller Co., general contractors, who employed an average force of about 1,700 men working a single 8-hr. shift. The general contractors' force was divided into steel erectors, bricklayers, carpenters and laborers, each class having several sub-foremen and one general foreman reporting directly to the superintendent. Their time was all recorded with ordinary brass checks and the record was verified three times a day at irregular intervals by the timekeeper's assistant, who visited different portions of the building and noted every man at work.

Clinton & Russell are the architects, Mr. James Dougan, chief engineer. Purdy & Henderson designed the structural steel work under the direction and supervision of the architects' engineer. Mr. A. E. Wells was consulting engineer for mechanical installation, electrical work and for sanitary equipment. The Geo. A. Fuller Co. is the general contractor.

A Producer-Gas Power Plant of 600 b.h.p. capacity was put into operation at the plant of David Rowan & Co., Glasgow, about a year ago, replacing a steam plant purchased in 1898. On account of an extension of the plant the company was considering the addition of steam units, but this idea was abandoned in favor of four 150-b.h.p. gas engines with suction producers burning Scotch anthracite coal. The four engines drive in parallel by belts to one main shaft, while three of them, in addition, are belted to direct-current generators. The engines were built by the National Gas Engine Co., have 30-in. stroke and 22½-in. cylinders, and run at 170 r.p.m. The flywheels are made heavy to diminish the cyclical vibration. The four gas producers are connected into an equalizer pipe; first, to enable any engine to be run from any producer, second, to equalize the suction effect between all the producers so that in case of failure in any producer it can be isolated without affecting the engines, and, third, when running one or two engines on night shifts to put all the producers on this load. This latter allows the other engines to be started without blowing up the producers. The guaranteed consumption of Scotch anthracite was 1 lb. per brake-horse-power-hour at full load, 1⅛ lb. at three-quarters load, and 1¼ lb. at half load, while the water consumption was guaranteed from 3½ to 5 imp. gal. per brake-horse-power-hour for the jackets, and for scrubbers and gas generators together not more than one gallon. The official tests, according to "The Engineer," London, from which these notes are taken, showed an average consumption of 0.854 lb. of coal per brake-horse-power-hour for a 10½-hr. run, with an average of only 117.65 h.-p. developed. The day after this test the coal burned was 0.845 lb., the average developed being 136 b.-h.-p. per engine. The total water consumption for jackets and producers was 4.2 lb. per brake-horse-power-hour in the first case, and 3.64 lb. in the second. Later runs totaling 295 hrs. show a total coal consumption per brake-horse-power-hour of 0.973 lb. with the water consumption about the same as given above. The coal consumption in indicated horse-power-hours for the last figures is about 0.73 lb.